THE UNIVERSITY OF ALBERTA

A STUDY OF CROWN MORPHOLOGY OF NEWLY-ERUPTED FIRST PERMANENT MOLARS IN WETASKIWIN (OPTIMUM FLUORIDE) AND CAMROSE (LOW FLUORIDE)

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled A Study of Crown Morphology of Newly-erupted First Permanent Molars in Wetaskiwin (Optimum Fluoride) and Camrose (Low Fluoride) submitted by William J. Simpson in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

Human tooth morphology has been studied. Two groups of newly-erupted maxillary and mandibular first permanent molars were compared. These groups consisted of:

(1) The molars of children who had ingested negligible amounts of water-borne fluoride from birth.

(2) The molars of children who had ingested optimum amounts of water-borne fluoride from birth.

The findings in the study led to the following conclusions:

(1) There was a definite trend toward greater mesiodistal and buccolingual diameters of teeth in the optimum fluoride sample. The difference reached significance in the case of the mesiodistal diameter of mandibular molars.

(2) Intercuspal angles were consistently greater in the optimum fluoride group than in the low fluoride group.

(3) Fissures were consistently shallower in the optimum fluoride group than in the low fluoride group. The difference was highly significant in one group of sections (from the mesiolingual cusp tip to the buccal (middle) cusp tip of the mandibular molars).

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THE PROBLEM

The research involved a study of the effects of the ingestion of optimum levels of fluoride on the gross crown morphology of human first permanent molars.

It was first necessary to select two comparable, reasonably accessible communities, one with virtually no fluoride, the other with 1.0 to 2.0 p.p.m. of fluoride in the drinking water. It was recognized that the two groups under study must be similar with regard to racial origins and socio-economic backgrounds. A sound procedure for establishing the similarity of the two groups had to be found and utilized.

The study of human structures always presents difficulties which are not encountered in animal experimentation. In most cases an animal can be sacrificed and the part being studies can be dissected out for examination. Alternative methods must be found in human studies.

Because of the complex nature of the early changes which take place in the developing tooth, it was felt important to review the literature in some detail on the effects of factors other than fluoride on tooth morphology. This necessitated a literature review which may appear quite lengthy.

In summary, the problem involved a study of the gross crown morphology of maxillary and mandibular first permanent molars in the children of two communities. These communities were comparable

with the exception of the fluoride content of the drinking water. Observation and comparison of most of the dimensions and characteristics of the clinical crowns of newly-erupted first permanent molars was undertaken.

PART I

BACKGROUND

Explanations for the caries inhibiting properties of water-borne fluorides have been sought mainly in the field of tooth chemistry and metabolism. (1), (2), (3), (4). The studies in these two fields continue in an effort to explain the exact manner of fluoride deposition in tooth substance. Although the preponderance of evidence which has accumulated to date suggests that the caries reducing effect is a biochemical or physical chemical phenomenon, several recent studies suggest that the ingestion of fluoride may also produce morphological changes in the teeth. The possibility even exists that such changes may be a factor in caries resistance.

Studies of tooth morphology have absorbed the interest of dental scientists since time immemorial, but it was Bodecker (5), (6) who, with his radical proposals in favour of prophylactic odontotomy, brought out the important relationship between pits and fissures and dental caries. Hyatt (7) reviewed the literature on pits and fissures as related to caries, and supported Bodecker's views on prophylactic odontotomy. Bossert (8), (9) related the shape of the occlusal surface of permanent and deciduous molars to caries incidence. He used stone models and made tracings of the occlusal surfaces with a Stratton surveyor and a dental pantograph. He found that caries was

more prevalent in molars with a steep angle between the cusps, and recommended reducing the slopes by grinding. On the basis of studies of 5,933 children from five to sixteen years of age, Brucker (10) deplored the practice of prophylactic odontotomy, claiming that only twenty-six to thirty-five per cent of first permanent molars are predisposed to caries. A meticulous study of pits and fissures in human molars and bicuspids was carried out in 1961 by Gillings and Buonocore (11). Teeth were mounted in plastic blocks and cut buccolingually into semiserial sections 130 microns thick at 450 micron intervals. The sections were mounted serially on three-inch by four-inch glass slides. Graphical reconstruction tracings were used and compared to a predetermined ideal enamel thickness. In all but one of fifty-two teeth, deeply invaginated fissure areas were noted, leading the investigators to the conclusion that these invaginations are normal, and not a result of some hypoplastic condition or developmental abnormality.

Heredity plays an important role in the development of teeth. Paynter and Graigner (12) say,

> Since the shape of teeth is established prior to eruption, it is determined by a combination of genetic inheritance and the multiplicity of environmental factors acting on the organism both pre- and post-natally, before eruption. Unquestionably the blueprint for basic tooth morphology, and even perhaps much of the detail is determined by inheritance.

Ludwig (13), in a study of 452 skulls and casts, found that morphologic traits varied in frequency of occurrence in different

ethnic groups. In monozygotic twins he found a significantly higher concordance than in the total Caucasian population.

Horowitz et al (14), studying anterior teeth of fifty-four pairs of adult Caucasian twins, found that genetically conditioned variations of high significance occurred in eight of the twelve anterior teeth being studied.

Gabriel (15), in a limited study of 230 maxillary central incisors, found 18 types of distinct mutant characters. He also found four mandibular first molars with three roots in monozygotic twins. He suggested that environmental factors may speed or retard the onset of caries, but that susceptibility or immunity is genetically determined.

The stability of design of human molars is emphasized by Jorgensen (16), who studied occlusal patterns of Dutch and Danish dead excavated from graves. He specifically tried to identify Dryopithecus patterns and classify them as Y, +, or X. (Dryopithecus is a primitive genus of the great apes, closely related to the anthropoids of India. These apes had a lower first molar with five cusps and a Y-shaped groove pattern.) He studied the changes in pattern in different ethnic groups, and found that Caucasians were well defined from other races by more frequent changes from Y to + to X patterns in succeeding generations. Mongoloids (Mongols, Chinese, Eskimos and American Indians) showed the least modification.

Dahlberg (17), considered the size of lower molar teeth

in relation to the number of cusps and the occlusal pattern in the same population group. He described the basic pattern as the Y5, or dryopithecoid pattern. The "Y" refers to the configuration of the grooves, and the "5" refers to the number of cusps. The teeth are classified as Y5, Y4, +5, and +4, depending on the occlusal groove pattern and the number of cusps. Dahlberg described the +4 pattern as the most evolutionarily advanced type, and the Y5 as the ancestral variety. The X category, although desirable for most studies, was not available in the 200 Melanesian dentitions from the Chicago Natural History Museum used in this work. Tooth size and the number of cusps were found to be related, but the difference in size occurred in only the mesiodistal dimension. Four-cusped molars are smaller than five-cusped molars provided the individuals have a common genetic background.

Cox et al (18), investigated the size of the cusp of Carabelli in relation to fluoride ingestion. They compared 318 casts of children from Kingston (fluoride deficient) with 351 casts of children from Newburgh (1.0 ppmF). The results indicated that there was no significant reduction in the number or the size of the cusp of Carabelli in human maxillary first permanent molars which had developed under optimum conditions of fluoride ingestion.

Of the many environmental factors affecting the teeth, diet is without doubt the most important in the initiation of decay after eruption, and in the determination of size, shape, and caries resistance or susceptibility. Mellanby's (19) work with vitamin A deficient diets is a milestone in dental research. Rats on vitamin

A deficient diets had abnormalities of the dental tissues increasing in severity in direct proportion to the length of time the mothers were on deficient diets. Mothers on the deficient diet twelve to thirteen weeks before casting of litters produced young with abnormal dental tissues. Mothers on the deficient diet fifteen to nineteen weeks showed changes in their own incisor roots and molar gingivae, and produced young showing marked changes from one week onward. Pathological changes in the molar gingivae were apparent in mothers on the deficient diet for twenty-four to twenty-five weeks before birth of litters. Gross abnormalities were discovered in the dental tissues of the offspring after a few days. Incisors of offspring were retarded and abnormal in shape and molar roots were affected. All offspring of rats on the deficient diet for thirty weeks were still-born. Rats on the diet for thirty-four weeks had severe dental defects, and did not get pregnant even with adequate vitamin E in the diet. In all groups the dental tissues of the young were more severely affected than those of the mothers. Dinnerman (20) studied vitamin A deficiency in human infants aged three to seven months. The mandibles were fixed in ten per cent neutral formalin for up to three months, decalcified in five per cent nitric acid and embedded in celloidin. Sections were cut transversely and anteroposteriorly and stained with hematoxylin and eosin. Specialized enamel-forming cells were found to be altered to a non-specialized stratified epithelium and enamel organs were atrophied. Accumulations of

epithelial debris were frequently encountered. Enamel hypoplasia was manifest as tears, canal-like defects or deeply stained interprismatic substance. Deposits of atypical enamel were sometimes found on the surface of the teeth. In several cases the Sheath of Hertwig was completely atrophied. It was concluded that vitamin A deficiency during active development and calcification of the teeth may produce degenerative changes in the specialized tooth-forming cells.

Irving (21) produced changes in the dental tissues of rats by using a rachitogenic diet. The experimental diet was introduced for twenty-eight days, after which the rats were partially starved or given a diet containing the correct Ca:P ratio (1:1.5) to induce healing. After three to six days the rachitogenic diet was resumed for a period of from three to forty-two days before sacrifice of the animals. Upper incisors and periodontal tissues were decalcified, and central longitudinal sections were stained with hemotoxylin and eosin. It was found that in the absence of enamel matrix formation the corresponding dentin does not calcify. Odontoblasts corresponding to the uncalcified dentin lost their characteristic appearance about eighteen days after calcification should have occurred. These odontoblasts laid down less dentin matrix, in which they became embedded. One can conclude that the odontoblasts receive a stimulus from the enamel organ at the time the enamel matrix is formed, which causes

dentin calcification. The effects of this stimulus persist throughout the life of the odontoblast. In the absence of the stimulus, the odontoblasts continue to lay down matrix for about eighteen more days, after which they regress.

McHenry (22) stresses the importance of calcium, phosphorus, vitamin D, ascorbic acid, fluoride and vitamin A in the healthy development of teeth.

Cox and Hagen (23) studied 296 pairs of upper primary molars and 202 pairs of lower primary molars on one side of the mouth. Pits were found more frequently in the second primary molars, suggesting that comparably better nutrition during formation of the first primary molars results in fewer pits in these teeth than in the second primary molars.

Shaw, (24), (25), reviewing nutritional relationships to dental caries, says, "The most important part of our environment is the food we eat". Sognnaes (26) found that female rats on a purified diet during pregnancy and lactation produced offspring which had a higher caries incidence than ones on a natural diet. Introduction of the purified diet after weaning caused an appreciable increase in caries incidence. If the purified diet was introduced during lactation and then given to offspring after weaning, there was a greater increase in caries incidence. If mothers were fed the purified diet before conception and throughout pregnancy and lactation and offspring received the purified diet after weaning,

these offspring showed the greatest caries incidence of all groups.

As early as 1934 Anderson et al (27) conducted a careful analysis of the importance of vitamin D in the diets of institutionalized children. They found that vitamin D reduced the number of cavities per child and reduced the number of children who developed new cavities in the three to ten year group, in both primary and permanent teeth.

Wynn et al (28) discovered that the incidence and extent of caries in Wistar strain albino rats at Emory University fed a purified high sucrose diet was considerably less than reported by Sognnaes for Long Evans strain rats fed a similar diet at the Harvard University Laboratories. Both diets contained the same amount of sucrose, but differed quantitatively in fat, protein, mineral and vitamin content. It was felt that the difference in caries experience may have been due to:

(1) differences in composition of "Harvard" and "Emory" diets.

(2) experimental conditions.

(3) genetic factors - different strains of rats were used in the two experiments.

(4) difference in drinking water.

A new experiment was initiated in which the experimental groups were fed either the Harvard or the Emory diet.

Twenty-four pairs of albino rats were selected at weaning

and placed on Emory and Harvard diets. The animals were surgically desalivated to speed up the carious process. The rats were sacrificed at eighty days, when their molars were dissected out and examined under a dissecting microscope for caries.

Littermate cotton rats were subjected to the same procedure, but since they are more caries susceptible than albino rats, they were not desalivated. These rats were sacrificed at 100 days. When there were three in the litter, one was placed on a stock diet of commercial animal food. The results tabulated in Tables 1 and 2 would suggest that dietary factors other than sugar account for the difference in the cariogenicity between the Emory and Harvard diets.

TABLE 1

(From Wynn et al (28))

CARIES IN ABLINO RATS FED EMORY AND HARVARD DIETS

Diet	Number of Animals	Average No. Carious Molars	Average No. Lesions	Average Caries Score
Emory	24	5.1 ($\pm$.06)	7.3 ($\pm$1.0)	24.9 ($\pm$3.9)
Harvard	24	10.2 ($\pm$1.4)	21.8 ($\pm$1.1)	83.8 ($\pm$5.4)

Sognnaes and Shaw (29), having observed that rats on a stock laboratory diet during tooth development were much more caries resistant than rats raised on a purified diet adequate in essential nutrients, designed a study to determine whether the apparent

developmental effect could be ascribed to differences in the mineral fractions of the two diets.

TABLE 2

(From Wynn et al (28))

CARIES IN COTTON RATS FED EMORY AND HARVARD DIETS

Diet	Number of Animals	Average No. Carious Molars	Average No. Lesions	Average Caries Score
Emory	17	3.6 ($\pm$0.4)	7.0 ($\pm$0.8)	15.4 ($\pm$2.1)
Harvard	20	6.0 ($\pm$0.7)	13.4 ($\pm$1.7)	41.9 ($\pm$7.6)
Stock diet	17	1.0 ($\pm$0.6)	2.0 ($\pm$0.1)	3.8 ($\pm$2.5)

They replaced the reagent grade salt mixture of the purified ration with an equivalent amount of the mineral ash obtained from the natural stock diet, Purina laboratory chow. Preliminary nutritional experiments had demonstrated the ability of the laboratory rat to use this mixture as a source of essential minerals. One hundred and ten normal and 129 desalivated Long Evans strain rats were used to find out whether desalivation would modify whatever effect was obtained by the ash ration. Within the two groups (normal and desalivated) a comparison was made between the caries susceptibility of rats on purified rations (Basic R-100 control) and of rats on the ash ration (experimental) either during tooth development alone or throughout the experimental period. Table 3 shows the results of

the experiment.

TABLE 3

(From Sognnaes and Shaw (29))

CARIES EXPERIENCE OF LONG EVANS STRAIN RATS FED A PURIFIED DIET OR A NATURAL ASH RATION

Condition of Animal	Number of Rats	Pregnancy and Lactation	Post Weaning	Average No. of carious Lesions
Normal	47	Basic R-100	Basic R-100	6.2
	50	Ash R-100	Basic R-100	4.2
	13	Ash R-100	Ash R-100	1.4
Desalivated	45	Basic R-100	Basic R-100	21.0
	61	Ash R-100	Basic R-100	23.2
	23	Ash R-100	Ash R-100	21.2

In a second part of the same study, a female rat was selected which came from a litter raised on the stock diet and was transferred to the purified (Basic R-100) diet for a period of ten months after tooth eruption. She remained on the purified diet until after her second litter was born, when she was transferred to the ash R-100 diet for the remaining ten months of the experiment, (i.e. until after her fourth litter was born and weaned).

Table 4 summarized the caries experience of the mother and her four litters.

TABLE 4

(From Sognnaes and Shaw (29))

THE EFFECT ON CARIES EXPERIENCE OF A NATURAL ASH SUPPLEMENT AT DIFFERENT STAGES OF TOOTH DEVELOPMENT

Family Relationship	Pregnancy	Lactation	Weaning (Post)	Average No. of Carious Molars	Average No. Carious Lesions
Mother	Natural	Natural	Basic R-100	0	0
1st litter (6 animals)	Basic R-100	Basic R-100	Basic R-100	4.1	8.3
2nd litter (9 animals)	Basic R-100	Ash R-100	Basic R-100	4.0	5.8
3rd litter (7 animals)	Ash R-100	Ash R-100	Basic R-100	3.0	3.5
4th litter (5 animals)	Ash R-100	Ash R-100	Ash R-100	0.8	1.0

Histologic examination of the teeth and jaws revealed no microscopically visible structural differences between the two groups, and the calcifying properties of both diets in terms of minerals and vitamins needed for development and calcification of the teeth were normal. It was also noted that there was no significant difference in the rate of growth of animals on the different diets. Total caries protection was not provided by the mineral fraction of the natural diet, but it would seem that certain mineral components were involved in the observed reduction of caries. The complete effect must have been partly dependent on other fractions of the natural diet. The ash of the stock diet was high in calcium,

phosphorus, chloride, magnesium, manganese and zinc, but increasing the amount of salt mixture in the purified diet by 50%, which would have increased the amount of these elements, failed to reduce caries. It would seem, therefore, that the minerals in the ash responsible for caries reduction must have been ones not now classified as essential nutrients.

Kruger (30) studied the effect of the "trace elements" manganese, boron, copper, fluorine, molybdenum, aluminum, iodine and vanadium on experimental caries in Albino rats. Suitable salts of the trace elements in normal saline were administered by intra-peritoneal injection during the major period of enamel mineralization of the first and second molars. In several separate experiments, groups of these elements at different dosage levels were tested for their caries reducing effects. The effect of individual elements, as well as their interactions, were analysed. The following results are of interest:

(1) Manganese seemed to show a tendency to predispose rat molars to an increased carious attack.

(2) Sodium fluoride produced a significant caries reduction.

(3) The addition of a solution of four mineral salts (boron, copper, manganese and molybdenum) to the fluoride solution reduced the effectiveness of the fluoride, and the four mineral salts without fluoride had no significant effect on rat molar caries.

(4) Both boron and molybdenum exerted a significant effect on rat molar caries.

(5) Copper showed sufficient effect to merit further study.

(6) Vanadium and iodine both exerted a significant effect on caries, while aluminum and iodine were ineffective.

(7) Significant effects were produced by the interaction: boron and fluorine, aluminum and fluorine, and aluminum and vanadium.

Nizel et al (31, 32) conducted two experiments on Golden Syrian hamsters, using the M.I.T. number 10 caries-producing diet. In the first experiment, the phosphorus level was doubled (2P) and in the second experiment it was quadrupled (4P) by adding metaphosphoric acid. These diets were fed to comparable groups of twenty hamsters. The second group received the diet for seventy days, after which they were fed a more cariogenic diet for an additional ninety days. In the 4P group, the molar teeth were "flatter-cusped, shallower-fissured and more lustrous" than those in the control and 2P groups. Caries incidence averaged eighty-seven to one hundred per cent in the two control groups, and zero to nine per cent in the two groups fed the high phosphorus diets. Figure 1 shows the contrast in the appearance of the two groups of teeth. Whether this is a systemic, a local or a combination effect requires further study. Nizel said:

If human clinical control studies which are currently under way confirm these animal and in vitro studies, optimum levels of phosphorus may prove to be as important as fluorine in the prevention of dental caries.

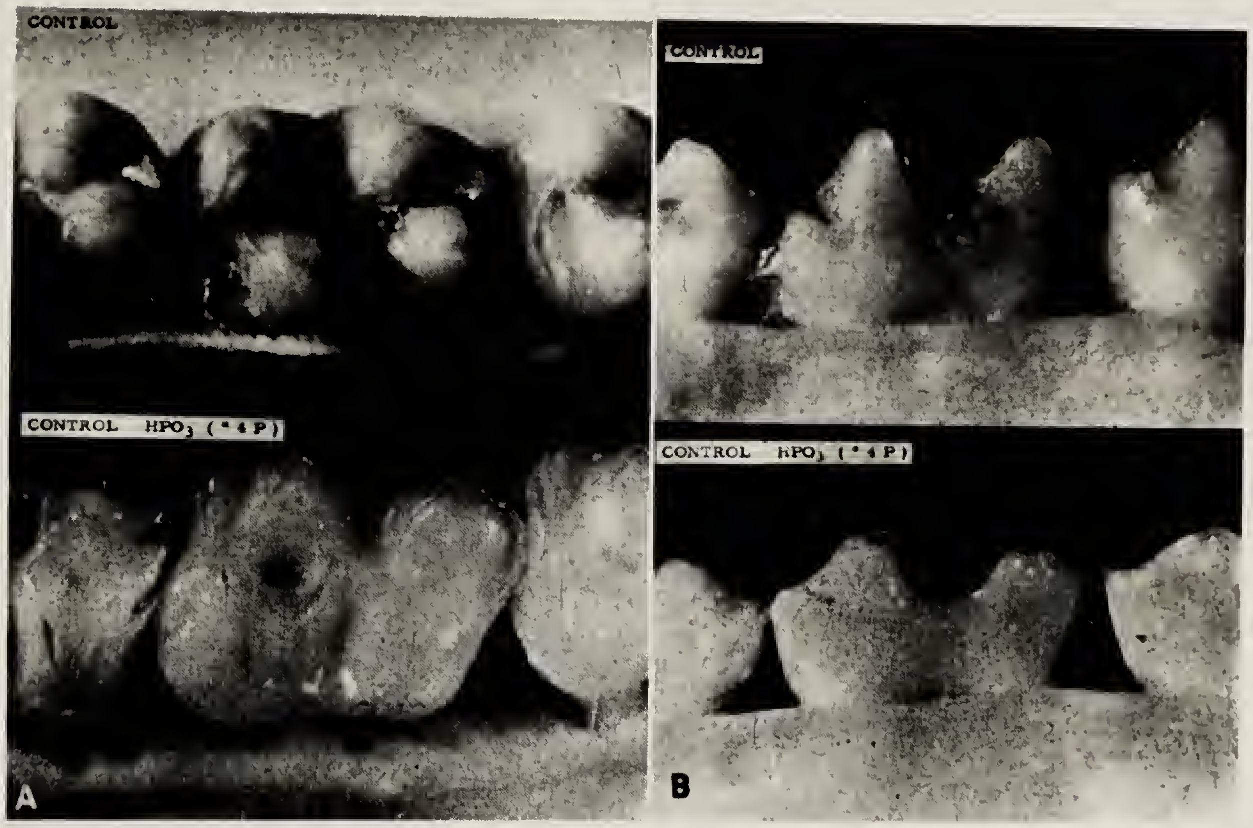


FIGURE 39. *A*, Occlusal view of hamster molars—note morphologic as well as caries difference between group on control diet and experimental (control + HPO_3) diet. *B*, Lateral view of same teeth.

Fig. 1.--(From Nizel (32))

Madsen and Edmonds (33) administered controlled amounts of a 0.01 per cent solution of sodium fluoride to cotton rats for short periods to determine whether there was any reduction in dental caries. Littermates divided into two groups were kept under the same conditions and fed an oatmeal cariogenic diet. The control group was given two drops of distilled water every hour during an eight hour period for three days after weaning. The experimental

group was given two drops (0.1 ml.) of 0.01 percent sodium fluoride solution on the same schedule. This amount of sodium fluoride solution provided a measured amount of fluoride about equal to that estimated to be normally consumed daily in a diet containing 45 ppm fluoride. The rats were sacrificed at forty days of age and the teeth scored for fissure caries. Table 5 shows the caries scores. Significant caries reduction was obtained in first molars. Second molars, which had not erupted at the time of fluoride supplementation, were not affected by the fluoride treatment. These results agreed with previous studies in which 45 ppm fluoride was added to an oatmeal diet fed ad libitum.

TABLE 5

THE EFFECT OF TWO DROPS OF 0.01% SODIUM FLUORIDE PER HOUR FOR EIGHT HOURS ON CARIES EXPERIENCE OF RATS

(From Madsen and Edmonds (33))

Group	No. of Rats	Caries Incidence ± SEM		Caries Extent ± SEM	
		1st Molar	2nd Molar	1st Molar	2nd Molar
Control	10	13.6±0.4	9.7±0.2	28.1±1.0	21.2±0.7
Experimental	9	5.0±0.1	9.2±0.3	9.8±2.3	19.0±0.8

It would appear that the observed cariostatic effect was not due to any morphological changes induced by the fluoride, as the affected teeth were erupting during the administration of fluoride.

Shaw and Sognnaes (34) studied the effect of fluoride on the caries-conduciveness of a purified ration. The purified caries-producing diet (R-100) was used as the control. Long Evans strain female rats were fed the purified R-100 diet throughout their early lives. Their litters were given either 6 ppm or 25 ppm fluoride in the form of sodium fluoride at different levels of development. The results are shown in Table 6 and Table 7.

TABLE 6

THE EFFECT OF 6 PPM FLUORIDE ON CARIES INCIDENCE OF RATS

(From Shaw and Sognnaes (34))

No. of Rats	Preg. & Lactation	Post-Weaning	Incidence of Caries	
			Av. No. Carious Molars	Av. No. Carious Lesions
35(mothers)	R-100	R-100	3.8	8.1
19(1st litter)	R-100	R-100+6ppmF	4.2	8.7
54(2nd litter)	R-100+6ppmF	R-100	4.0	8.5
25(3rd litter)	R-100+6ppmF	R-100+6ppmF	3.7	7.9

The reduction in carious lesions from the first litter to the third litter reached significance, but there was no difference in the number of carious molars.

TABLE 7

THE EFFECT OF 25 PPM FLUORIDE ON CARIES INCIDENCE IN RAT MOLARS

(From Shaw and Sognnaes (34))

	Diet History			Incidence of Caries	
No. of Rats	Pregnancy	Lactation	Post-Weaning	No. of Carious Molars	No. of Carious Lesions
	Maturation Period				
7	R-100	R-100	R-100	4.7	9.3
4	R-100	R-100+ 25ppmF	R-100	3.8	6.5
4	R-100	R-100+ 25ppmF	R-100	4.2	4.8
	Post Development Period				
8	R-100	R-100	R-100	4.4	10.4
9	R-100	R-100	R-100+ 25ppmF	4.0	9.4

The reduction in carious lesions from the first litter to the third litter reached significance, but there was no difference in the number of carious molars. The investigators came to the following conclusions:

(1) Addition of 6 to 25 ppmF to a caries-producing diet produces no significant reduction in caries.

(2) The absence of caries in rats fed a natural stock diet during tooth development cannot be attributed to the fluoride in that diet.

(3) There must be other minerals or ratios of minerals which are major factors.

Grainger and Coburn (35) related caries protection from fluoride to the age and stage of tooth development of children at the time of their arrival in fluoride-endemic communities. Data was obtained from dental charts in Aylmer, Ontario (1.2 ppmF) and from examination of South Dorchester children (F in varying amounts). It was found that the caries incidence in first primary molars was decreased in children who arrived in the fluoride-endemic community before the first birthday. The same observations were made regarding first permanent molars. Children arriving before eruption of the first permanent molars had a significantly reduced caries incidence compared to children who arrived after eruption of their first permanent molars. The caries reduction in first permanent molars was decreased in children who arrived after eruption of their first permanent molars. The caries reduction in first permanent molars of children who arrived before their third birthdays actually equalled or exceeded that observed in the first permanent molars of native born children.

Development of caries-resistant and caries-susceptible strains of rats (36) has facilitated studies of pits and fissures under controlled conditions. Kifer et al (37) found that fissures in lower molars of caries-susceptible animals were significantly wider than those of caries-resistant ones. This study suggested the possibility of more general morphological differences in caries-resistant and caries-susceptible teeth as a result of altered

nutritional states.

Paynter and Grainger (38) fed pregnant female rats various diets, in one of which the only variable from the control was 12 ppm of fluoride. The young were sacrificed at the twenty-second day and the maxillary right first molar was dissected out and photographed from the buccal, lingual and occlusal aspects. The photographs were enlarged approximately 26.5 times and examined for:

(1) the greatest mesiodistal diameter at the cervix,

(2) the buccolingual diameter of the crown,

(3) the angle between the sides of the two mesial fissures observed from the lingual,

(4) the depth of this fissure measured from its apex to the line joining the tips of the cusps,

(5) the shape of the apex of the fissure -- whether rounded, medium or sharp.

The rats on the fluoride diet had smaller teeth than the controls without relation to overall weight. The most striking differences appeared in the cervical diameters. Fissure angle and depth in the fluoride group showed very little difference from the control. Rats on a vitamin A deficient diet or on a high phosphate diet had smaller teeth proportionate to the smaller size of the animals, increased fissure angles and greatly reduced fissure depth. The authors could not say whether the change in the fissures was a specific effect occurring only in the cases of the greatest stress

or if it was a differential response produced in the smaller tooth due to the drawing together of the conical shaped cusps to give the effect of shallower fossae. It was concluded that measurable size and morphological differences can be produced in rat teeth by variation of the diet.

Kruger (39) administered intraperitoneal injections of sodium fluoride (0.108 mg. F per day) to rats during the period of amelogenesis. He used ten litters of rats in the experiment, with two control and two experimental rats from each litter. One control and one experimental animal from each pair was killed at twenty-one days and the teeth were examined morphologically. The occlusal of each tooth was photographed and enlarged, then mesiodistal sections were photographed and enlarged. Measurements of these photographs revealed:

(1) smaller (but not significant) mesiodistal diameter in experimental teeth,

(2) shallower mesial and distal fissures in the experimental teeth (significant),

(3) wider fissures (but not significant) in the experimental teeth.

Holloway et al (40) varied the carbohydrate and protein content of rat diets and studied the tooth morphology of the offspring, which were carried on such diets until the teeth erupted. Eruption of third molars was delayed seven days in rats on low protein.

Measurements of photographic enlargements of the teeth of rats on the low protein diet revealed that the mean of every measurement was significantly smaller than in the controls. Differences were least in the first molars, greatest in the third molars. Animals in the low protein groups were smaller, but there was no definite correlation between animal size and tooth size. This was stated to be clear evidence that tooth size can be influenced by environment during development, but, because of the possible role of starvation, these results cannot necessarily be interpreted as a specific influence of protein deficiency.

McMurchy (41)(42) studied the effects of dietary phosphate on tooth development in the hamster. Three groups of hamsters were fed a basic cariogenic diet (Nizel and Harris). Group A, the control, was given the basic diet. Group B had disodium hydrogen orthophosphate (Na_2HPO_4) added to double the total phosphorus value, while group C was fed sufficient disodium hydrogen phosphate to quadruple the phosphorus value. The part of the study related to gross morphology involved removal of the maxillary right first molar, photographing it and projecting the negative. The image was traced and measured for mesiodistal width and for the angle formed by the mesiobuccal and middle buccal cusps. The measurements of the mesiodistal diameter of first molars revealed that groups A and C were not significantly different, and that the molars in Group B were, on the average, smaller than those of the other two groups. Measurement of

the mesiodistal diameter of second and third molars showed no significant differences between the three groups. Cuspal angles were found to be smaller in groups B and C than in group A. The same trend appeared in second molars. Studies of roentgenograms of quadrants from hamsters of the same age suggested that groups B and C lagged slightly behind the normal group A in tooth development and time of tooth eruption. It was concluded that increased dietary phosphate:

(1) decreases cuspal angles,

(2) does not influence mesiodistal length of teeth,

(3) retards eruption times.

In his discussion, McMurchy points out that the animals in group B were smaller, which may have been related to the smaller size of their teeth. It was discovered that the water supply outlets in cages housing group B had been placed higher than in the other two groups. This raises the question as to whether group B suffered from a lack of fluid intake at an early age.

An analysis of McMurchy's measurements is shown in Tables 8 and 9. In view of the stated unreliability of group B (2P), and looking only at the comparisons between groups A and C (4P), one might accept the statement that there is a trend toward smaller cuspal angles with increased dietary phosphate. However, judging from these data, it would seem that cuspal angles in maxillary second molars were not significantly affected. McMurchy states that measurement

of cuspal angles of twice the number of specimens since reporting his study seems to confirm the trend to smaller angles in groups B and C.

TABLE 8

THE EFFECT OF DISODIUM HYDROGEN ORTHOPHOSPHATE ON TOOTH DEVELOPMENT OF HAMSTERS COMPARING GROUP A (CONTROL) AND GROUP B (2P)

Treatment	$\bar{X}_A$ mm or °	$\bar{X}_B$ mm or °	$\bar{X}_d$ mm or °	"t" test p
Mesiodistal Length (Maxillary Right First Molar)	15.46 SE=0.092 (n=14)	14.98 SE=0.180 (n=9)	0.48 SE=0.202	<0.02*
Mesiodistal Length (Maxillary Right Second Molar)	12.50 SE=0.008 (n=12)	12.27 SE=0.010 (n=9)	0.23 SE=0.134	0.19
Mesiodistal Length (Maxillary Right Third Molar)	10.15 SE=0.04 (n=6)	9.98 SE=0.10 (n=4)	0.17 SE=0.374	0.65
Angle Between Cusps (Maxillary Right First Molar)	79.00 SE=0.44 (n=14)	75.44 SE=1.66 (n=9)	3.56 SE=1.45	<0.02*
Angle Between Cusps (Maxillary Right Second Molar)	86.73 SE=1.27 (n=11)	85.28 SE=3.28 (n=9)	1.45 SE=2.14	0.5

$\bar{X}_d = \bar{X}_A - \bar{X}_B$ where $\bar{X}_A$ = control mean

$\bar{X}_B$ = experimental mean

SE = standard error

* statistically significant

TABLE 9

THE EFFECT OF DISODIUM HYDROGEN ORTHOPHOSPHATE ON TOOTH DEVELOPMENT OF HAMSTERS COMPARING GROUP A (CONTROL) AND GROUP C (4P)

Treatment	$\overline{X}_A$ mm or °	$\overline{X}_C$ mm or °	$\overline{X}_d$ mm or °	"t" test P
Mesiodistal Length (Maxillary Right First Molar)	15.46 SE=0.092 (n=14)	15.43 SE=0.080 (n=14)	0.03 SE=0.1216	0.8
Mesiodistal Length (Maxillary Right Second Molar)	12.50 SE=0.008 (n=12)	12.26 SE=0.013 (n=13)	0.24 SE=0.145	0.1
Mesiodistal Length (Maxillary Right Third Molar)	10.15 SE=0.04 (n=6)	9.73 SE=0.05 (n=6)	0.42 SE=0.09	0.16
Angle Between Cusps (Maxillary Right First Molar)	79.00 SE=0.44 (n=14)	75.14 SE=1.42 (n=14)	3.86 SE=1.365	0.01*
Angle Between Cusps (Maxillary Right Second Molar)	86.73 SE=1.27 (n=11)	85.08 SE=0.91 (n=12)	1.65 SE=1.475	0.26

$\overline{X}_d = \overline{X}_A - \overline{X}_C$ where $\overline{X}_A$ = control mean

$\overline{X}_C$ = experimental mean

SE = standard error

* statistically significant

Grainger, Paynter and Shaw (43) studied the differences in morphology and size of teeth of caries-susceptible and caries-resistant rats. They dissected the maxillary right and left first

molars from twelve- to fourteen-day old rats. The molar was mounted, photographed and enlarged, and measurements were made of mesiodistal diameter of the crown, mesiodistal diameter of the cervix, bucco-lingual diameter of the crown, and visible depth and angle of the sides of the distal occlusal fissure as seen from the lingual aspect of the whole crown. The left molar was bisected mesiodistally and occlusocervically. The cut surface was photographed and enlarged and measurements were made of the depth of the mesial occlusal fissure and of the angle of the sides in the lower third of the same fissure.

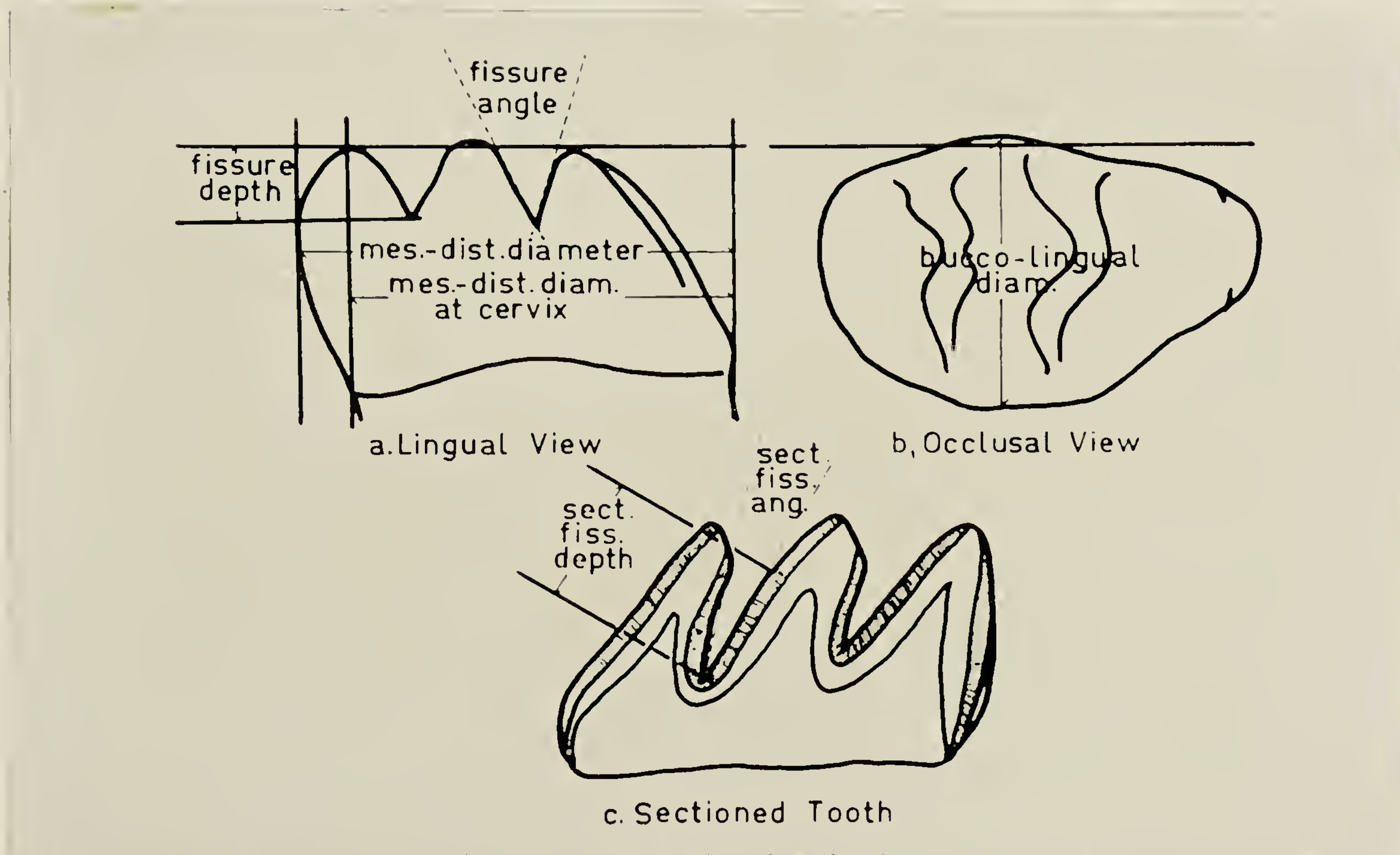


Fig. 1. Outline drawings of the lingual and occlusal aspects of the upper right first molar of a rat and of the cut surface of a hemisectioned tooth showing the method of measuring the tooth characteristics.

Fig. 2 (From Grainger et al (43))

There were no significant differences in tooth measurements between male and female. This conclusion was based on an analysis of variance for each value.

There were significant differences between litters in the caries-resistant group for all measurements except the angle of the sectioned fissure.

In the caries-susceptible group, there were no significant differences between litters in the measurement of the fissure angle, whether measured from the lingual view or from the section. There were also no significant differences between susceptible litters in the measurements of the depth of these sectioned fissures. Other measurements differed between litters.

Teeth from caries-susceptible rats appeared to be smaller than those of caries-resistant rats in mesiodistal diameter, particularly at the cervix. They had shallower mesio-occlusal fissures, and the sides of these fissures were more nearly parallel at the base. (Fig. 3)

After computing the correlations between the different measurements, the investigators concluded that:

> While the depth of the fissure as measured in this study could be a function of tooth size, the fissure depth was the factor most strongly associated with the caries susceptibility of the tooth, the mesiodistal diameter of the crown at the cervix being perhaps only secondarily associated with caries susceptibility.

The writers caution against the assumption of a cause-effect relationship in their study. For example, a morphological

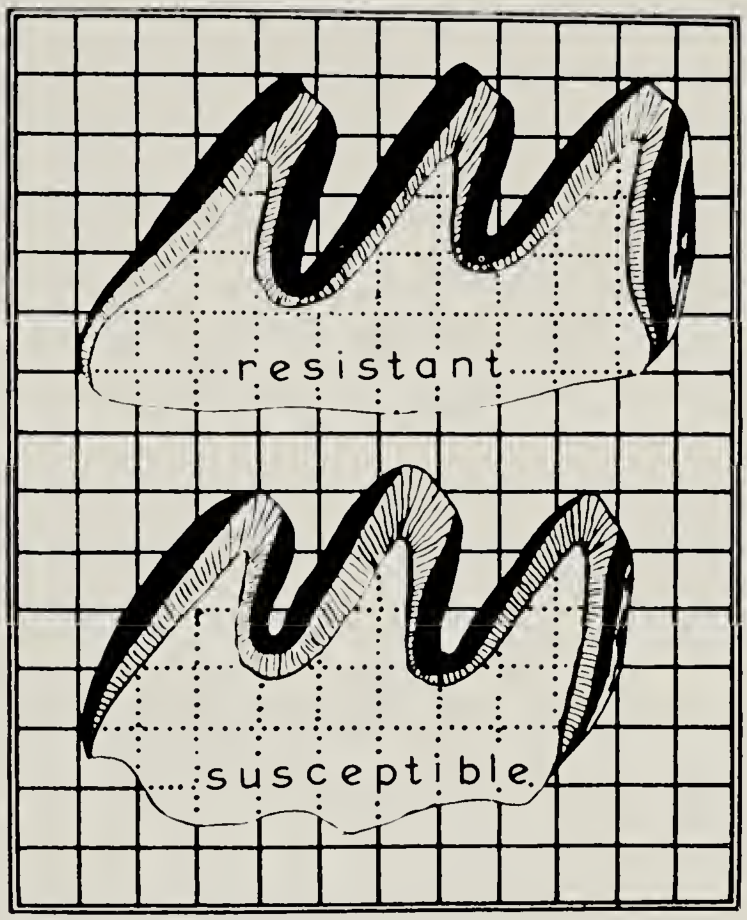


Fig. 1.—Cut surfaces of hemisectioned upper first molars illustrate size and shape differences between teeth of Harvard strain caries-resistant and caries-susceptible rats.

Fig. 3 (From Paynter and Grainger (38))

characteristic such as a fissure cannot cause tooth decay, but in humans it is a very strong predisposing factor. They also point out the apparent difference between their results and those of Kifer et al (37) who found the fissures in mandibular molars of caries-susceptible rats wider than the fissures in the mandibular molars of caries-resistant rats. This difference is better understood when one realizes that the width of the fissures in the study

of Kifer et al was measured in a different location (at the occlusal rather than the basal third) on the mandibular molar, whereas Grainger et al studied maxillary molars. They point out that a study of the fissures of maxillary molars suggests that the fissure in susceptible animals is funnel-shaped, with a narrow base and wide-open mouth, whereas the fissures in the maxillary molars of the resistant strain are more smoothly V-shaped. Thus, if the same measurements had been made in the same way in both studies, they possibly could have agreed.

Table 10 summarizes the findings of Grainger et al (43) on morphological differences between molars of caries-resistant and caries-susceptible rats and the findings of Grainger and Paynter (38), who studied the morphological effects of fluoride (12 ppm), low vitamin A and high phosphate on rat molars.

TABLE 10

GENETIC EFFECT (43) AND DIETARY EFFECTS (38) ON THE MORPHOLOGY OF RAT MOLARS

Measurement	Low Vit.A	Flouride 12 ppm	High Phosphate	Caries Resistant	Caries Susceptible
Mesiodistal Diameter (Cervical)	smaller	smaller	smaller		smaller
Mesiodistal Diameter of Crown	smaller	smaller	smaller		smaller
Buccolingual Diameter (Cervical)	smaller	smaller	smaller	no significant difference	tends to be smaller
Angle of Fissure	no significant difference		greater		smaller
Depth of Fissure	no significant difference		more shallow		more shallow
Size of Animal	smaller	larger	smaller	n.a.	n.a.

Paynter and Grainger (44), reviewing the influence of nutrition and genetics on morphology and caries susceptibility, point out that genetic inheritance is probably the most important determinant of dentition, influencing general arrangement of teeth in the arch, eruption time, and also finer anatomic details such as occlusal fissure patterns, cusp arrangements and tooth size. They point out that abnormal variation in tooth form in animals can be produced experimentally by altering the environment of the teeth through nutrition. These alterations in morphology may be accompanied by variations in caries-susceptibility to pit and fissure caries. These reviewers explain that the relation in human molars between tooth size and caries-susceptibility is not so clear-cut partly because of limited research, and partly because the apparently weak relationship may be masked by the severe caries attack common to humans living in modern urban areas. They observed that in several communities in Ontario and Newfoundland larger mandibular molars are more caries-susceptible than smaller ones. Larger first molars were found to erupt later than smaller molars in the Burlington study (46).

Kruger (45) investigated the effects of the trace elements boron, fluoride and molybdenum on the morphology of rat first mandibular molars. These trace elements were injected intraperitoneally during the period of amelogenesis as follows:

control: a normal saline solution

boron: a solution of boric acid in normal saline so mixed that the amount injected into each rat daily provided approximately 0.025 mg. of boron.

fluoride: a solution of sodium fluoride in normal saline providing approximately 0.108 mg. of fluoride daily.

molybdenum: a solution of ammonium molybdate in normal saline providing approximately 0.007 mg. of molybdenum daily.

The experiment was divided into three periods to study the effects of the trace elements at different stages of enamel formation. The periods were arbitrarily chosen as the third to the sixth days inclusive, the seventh to the tenth days inclusive and the eleventh to the fourteenth days inclusive.

Littermates were used for control versus experimental animals to minimize any genetic between-litter differences, and treatments were randomized within litters to minimize bias in selecting animals.

All animals were weighed at intervals between the fifth and twenty-first day, at which time they were sacrificed, and the first mandibular molars dissected from the mandibles.

Occlusal photographs were taken of all experimental and control teeth for observation of gross alterations. The teeth were sectioned mesiodistally at approximately the greatest mesio-distal diameter with a fine carborundum stone in a dental handpiece.

A drawing of each section was made, using a microscope drawing apparatus attached to the Leitz binocular prism magnifier. This method produced outline drawings approximately twenty times actual size. The following measurements were made in each group of teeth:

(1) width of mesial fissure

(2) width of distal fissure

(3) depth of mesial fissure

(4) depth of distal fissure

(5) maximum mesiodistal diameter

(6) cervical mesiodistal diameter

Boron did not alter crown morphology when administered during the first and third experimental periods, but administration during the second experimental period produced wider and shallower mesial and distal fissures. The average depth of the mesial fissure in the experimental teeth treated during this period was less than half the average depth in the control teeth. Boron produced no alteration in mesiodistal diameter.

Fluoride administration during the first experimental period produced no significant morphological changes, but administration during the second period resulted in:

(1) a wider and shallower mesial fissure

(2) a shallower distal fissure, which tended to be wider.

When administered during the third experimental period,

fluoride produced a significantly reduced maximum mesiodistal diameter, but no other significant changes.

Molybdenum did not alter crown morphology during the first and third experimental periods, and the alteration resulting from its administration during the second period was not as marked as the changes affected by boron and fluoride. Molybdenum did produce a significantly wider mesial fissure.

Observation of the enlarged occlusal photographs revealed some interesting changes in the molars of experimental animals. All molars of rats treated with boron during the second experimental period had very shallow mesial fissures, and in four cases out of twenty the mesial fissure was completely eliminated. The mesial and distal fossae of the molars of fluoride-treated rats (in the second period) were much shallower than those of the control rats and the occlusal surfaces appeared flatter than those of molars treated with the other elements. The molars of rats treated with molybdenum during the second experimental period appeared different from the other two groups. In the molybdenum group, the fissure was widest and deepest on the buccal and tapered off in width and depth as it approached the lingual surface.

Examination of the body weights of the rats in the various experimental and control groups showed no correlation between tooth size and animal size. Furthermore, treatments had no effect on weight gains. At the selected dosage levels of the

three elements, the experimental animals gained at the same rate as the control animals, and all groups attained comparable weights at twenty days.

In this same study, molars and incisors were examined histologically. No changes were observed in the developing teeth of boron-treated rats. Fluoride administration produced a "calcio-traumatic response" in the enamel matrix and dentin. In some areas the ameloblast layer showed cellular changes, and the deposition of the enamel matrix was retarded. A similar "calcio-traumatic response" also followed the administration of ammonium molybdate. In some teeth the dentin had an interglobular texture.

Grahnen and Ingervall (47) used "Zelex" impressions and artificial stone models to compare tooth width, arch width, arch length, height of vault and occlusal relations in a group of caries-resistant and caries-susceptible men. The only significant difference was a lower vault in the resistant group.

In 1962 Paynter and Hunt (48) reviewed the 1956 and 1961 findings of Paynter and Grainger (38)(50) and the 1960 findings of Shaw (51). They mentioned an interesting finding incidental to a move of the animal quarters from old sunlit quarters to new quarters designed to almost exclude sunlight. It was discovered that the animals, (all of which were getting no vitamin D before the move), developed bone changes indicative of rickets. It was also found that animals whose teeth developed in the old sunlit

quarters remained relatively resistant to decay, while those whose teeth developed in the new quarters were much more susceptible. To control the highly sensitive vitamin D effect in subsequent experiments, the animal rooms are being blacked out and vitamin D intake is controlled through the diet.

These researchers report the initiation of two long-term studies, one to test the effects of fluoride and vitamin D on tooth morphology and caries susceptibility and their interaction, the other to test the effect of various calcium and phosphorus levels and their interaction, both with and without vitamin D in the diet. Mothers were kept on the experimental diet through pregnancy and lactation (and on D-deficient diets for three weeks before mating). At weaning the young were anesthetized and the upper right first molar extracted for morphological study. The animals were maintained for 120 days on a cariogenic diet, then examined for caries following this period. Fluoride supplement and vitamin D deficiency both tended to reduce tooth size. Deficiency of vitamin D results in an increase in the number of cavities and a large increase in cavity size.

Studies related to changes in the teeth resulting from changes in calcium and phosphorus levels in the diet are still in progress. These authors point out that although it has been shown that tooth form is subject to alteration during development, further knowledge of how teeth develop is necessary in order to

understand the processes involved. To study this problem they reconstructed developing tooth germs at various ages, and made autoradiographs of developing teeth after injection of rats with tritium-labelled thymidine in order to follow mitotic activity. The teeth were then reconstructed in the following way: sections twelve microns thick were cut from developing upper first molars from rats at various ages from nineteen days in utero to ten days after birth. Every second section was projected on a sheet of plastic one-sixteenth of an inch thick at a magnification of sixty-six times, permitting construction of models unchanged in proportion from the originals. The plastic was cut along the dentino-enamel junction so that two models were made of each tooth germ, one of the dental papilla including dentin where present, the other of the enamel organ including enamel where present. The models were measured at the dentino-enamel junction for:

(1) mesiodistal diameter

(2) buccolingual diameter

(3) crown height

(4) length of the sides of the grooves

(5) the distance from cusp tip to cusp tip

(6) the angles between the cusps and the base of the crown

It was found that the state of development of the tooth varies widely in relation to the age of the rat, but it was possible to

visualize the changes that occur as the crown develops and attains final form. The data obtained indicated that until at least ten days, tooth size is a factor of the log of age; the same was the case with regard to buccolingual diameter and crown height. The mesiodistal diameter quadrupled in size during the two days before birth to a final diameter of about one and one-half times that at birth. After other measurements were more or less established, crown height continued to increase. During the period of rapid growth just before birth, cusps became apparent on the models. (Fig. 4)

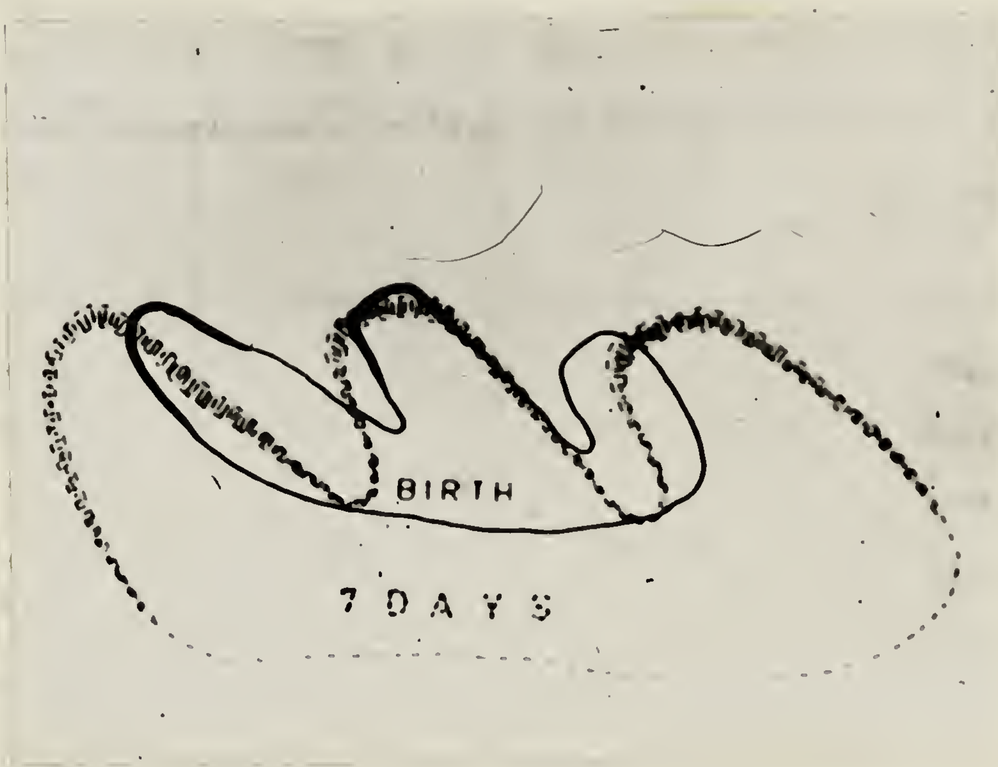


Fig. 4.--Mid-sagittal section of a developing rat molar at birth, superimposed on a similar drawing of a tooth at seven days. (From Paynter and Hunt (48))

This aspect of the study showed that, in the rat maxillary molar, the critical period for effecting changes in morphology is during the period from shortly before birth to about three days after,

when groove depth and the basic shape has been established.

This statement appears to disagree with Kruger's (45) observation that the greatest morphological changes were effected between the seventh and tenth days after birth.

The autoradiographs revealed an intimate relationship between cell divisions in the inner enamel epithelium (i.e. growth in size of this cell layer) and the deposition of dentin on its pulpal surface. Since the grooves continue to deepen primarily by mitotic activity of inner enamel epithelium, their final depth is determined by the interaction of cell division in an epithelial layer on the one hand, and the rate of connective tissue cell differentiation and dentin synthesis on the other. A brief review of how this phenomenon affects human tooth form and possibly caries susceptibility is quoted as follows:

> One primary morphological difference between the form of rat and human molars is that in the rat, the grooves which run buccolingually across the tooth are not bounded on each side by a marginal ridge. Thus they probably act more as spillways than do the grooves in human teeth. On the other hand, the grooves running across human molars are bounded on the mesial and distal sides of the crown by high marginal ridges and on the buccal and lingual sides by intercuspal ridges. In both instances the occlusal edge of the ridges are some distance above the deepest point on the crown surface. Thus as dentin is deposited in the tips of the cusps, and then spreads out to unite the cusps, the first union occurs along the marginal ridges and buccal and lingual intercuspal ridges. Once this dentin is laid down and to some degree mineralized, no further increase in the overall size of the crown at the occlusal surface can occur. At this time the centre of the crown, i.e. grooves and fossae, are still composed of soft tissue, and the cells of the inner enamel epithelium in this site are still dividing, but now within a fixed boundary. At this stage, if something interfered with

dentinogenesis without also reducing mitotic rate in this epithelial layer, this layer would in effect become "too big" for its boundaries, and would either bulge up to wrinkle the surface, or more likely dip down to form a deeper groove. Conversely, if dentin apposition were speeded up without concomitant increase in mitotic rate, theorically the grooves would be shallower.

> A similar process affects the size of the crown around the cervix, where size is determined by mitosis in the epithelial cells of the tooth sheath or cervical loop and dentinogenesis around the periphery of the crown. Factors causing deep grooves should thus result in teeth larger at the cervix. Of interest in this respect is the observation that the human lower first molars that show most pit and fissure susceptibility also tend to be larger at the cervix.

Paynter and Grainger (49) made a similar report in 1962 in which they included a diagram showing the deposition of enamel and dentin in a human molar. (Fig. 5)

In a more recent report (52) Paynter says:

> Morphological changes experimentally produced through nutrition are sometimes related to changes in caries susceptibility, but not in a predictable manner. The mechanism by which tooth form is altered is not understood, nor indeed are the details of normal development of the rat molar.

He described an improvement in the reconstruction of developing tooth germs. Tracing paper was used instead of plastic. Estimates of buccolingual width were made by direct measurement of models. The enamel organ including enamel matrix, and the dental papilla including dentin, were then reconstructed individually for each tooth germ. All measurements were made on the model of the papilla, i.e. at either the future or actual dentino-enamel junction.

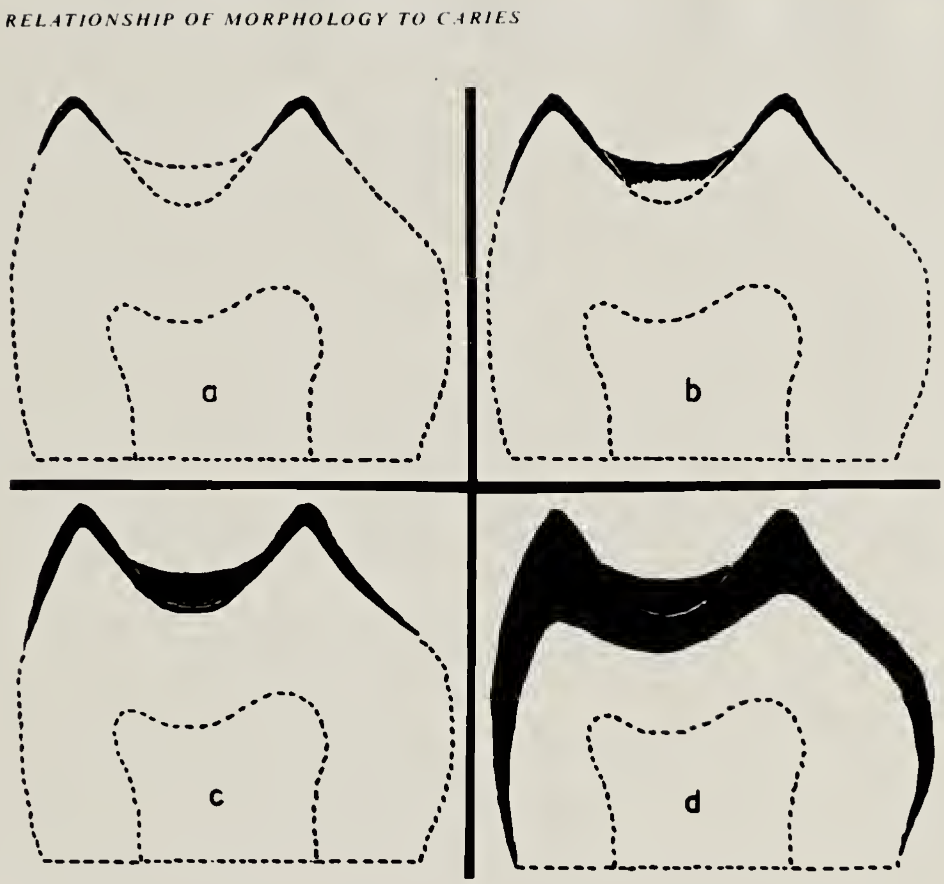


FIG. 1
Diagrammatic drawing showing the dentino-enamel junction of the distal cusps and marginal ridge of a human molar, with the pattern of dentine apposition superimposed.
(a) deposition in cusp tips only, (b) cusps united along the marginal ridge, (c) cusps united under the groove, (d) cervical dimension established.

Fig. 5.--(From Paynter and Grainger, (49))

It was found that using the time of birth as a basis for estimating age was not satisfactory because of the variation both in time of birth and the exact time of fertilization. Relatively small variation in time can produce a large difference in state of development, particularly during the early and very rapid growth of the tooth germ. For this reason the time of copulation was used as the

base from which age was estimated in the latest series of reconstruction models. Measurements of the models confirmed that the size of the molar tooth germ is a factor of the log of age until nine to ten days after birth, (thirty-one days after copulation). Cusp tips moved apart until about the time the dentin was deposited over their tips at twenty-three days after copulation. Dentin appeared first in the distal and central cusps and later in the mesial cusp. A complete bridge of dentin was formed under the base of the sulci by about twenty-eight days, at which time the grooves ceased to grow deeper. Enamel deposition followed the dentin pattern, beginning about two days after the appearance of dentin.

Parikh (53) studied the effect of low dosages of sodium fluoride on tooth development. He used seven groups of rats:

Group 1.	Injected with distilled water
Group 2.	No treatment
Groups 3 to 7.	Injected with six to fifty micrograms of fluoride daily

The animals were sacrificed after two, three, five, seven, ten, twelve, fifteen, and eighteen doses. Jaws were fixed, decalcified and sectioned. Only those on fifty micrograms of fluoride showed microscopic changes. There was an effect on the ameloblastic layer and retardation of calcification of the enamel matrix. Dentin showed an interglobular texture. Mild hyperemia was sometimes seen.

Research into morphological changes in human teeth related to optimum levels of water-borne fluoride has been limited. A preliminary report from the Division of Dental Research, University of Toronto, (54) suggests that the observed effect of fluoride on tooth size in rats is also apparent in humans. This report was based on observation of grade three and grade eight pupils in the fluoride-endemic town of Mount Forest, Ontario.

In a personal communication (52) Dr. R. M. Grainger commented as follows on the size of human teeth related to caries based on his observations at Thorold and Burlington, Ontario.

> On the average, the carious teeth are about 0.3 mm. larger buccolingually than the noncarious teeth. We have confirmed this many times. Female teeth are about 0.3 mm. smaller than male teeth. Larger teeth are, on the average, earlier erupters. (This statement disagrees with the Burlington report of 1957 (46)). We could not detect what might be called a fluoride tooth form.

Wallenius (56) took "Zelex" impressions of 419 school children (233 boys, 196 girls) from districts with 0.5 to 1.0 ppm. fluoride. He poured models in "artificial stone" and measured from tooth contact to tooth contact with a Columbus measure. He found that there was an increase in tooth size proportional to the increase in fluoride content up to 1.0 ppm. He advanced two theories which might explain the phenomenon:

(1) that an eventual change of crystallization increases tooth width.

(2) that small amounts of fluoride stimulate the organism.

Atallah (57) commented that changes in form and size of teeth have sometimes been observed in fluorine poisoning. He measured the mesiodistal diameter of 10,000 teeth on models of 419 school children from fluoride-endemic districts in Egypt. His statistical analysis showed a tendency toward wider teeth with increased fluoride in the drinking water. The increase in width was about 1.7 per cent. Atallah also mentioned the two theories advanced by Wallenius as a possible explanation of the observed increase in tooth width.

Cooper and Ludwig (58) studied tooth morphology as well as bigonial and bizygomatic widths of seven to nine-year old children in three communities in New Zealand. The City of Napier has a low caries experience which seems related to trace elements (e.g. molybdenum, fluoride) in foods. Hastings has had fluoridated water for ten years, and Palmerston North was used as a control. Mesiodistal and buccolingual measurements were made of mandibular first permanent molars. Cusp height and convexity of the buccal surface of maxillary first permanent molars were recorded. These measurements were made from complete dental casts poured in "D.P." Elastic Impressions.

It was found that the mean mesiodistal diameter and the mean buccolingual diameter were both less in Hastings, the fluoridated town, than in the control town of Palmerston North. Mean cusp height

and mean buccal convexity were also significantly smaller in the fluoridated city.

The molars of Napier children showed no significant change in mesiodistal or buccolingual dimensions, but there was a reduction in cusp height and in convexity of the buccal surface.

Palmerston North children had slightly greater bigonial widths than both Hastings and Napier children.

The authors hypothesize that the greater bonding energy of fluoride produces a decrease in the dimensions of the crystal lattice, resulting in smaller teeth.

The observations of human molars by Wallenius (56) and Atallah (57) disagree with the observations on experimental animals in North America and Queensland and with the more recent observations on human molars by Cooper and Ludwig. (58) In all the human studies reported to date, the measurements were taken from complete dental casts poured in alginate impressions. Considering the small differences in morphology that appear to result from fluoride ingestion, one wonders about the accuracy of the technique.

My review of the literature pertinent to the present study leads me to these conclusions:

(1) There is evidence from human and animal studies that the caries-reducing effect of fluoride is biochemical in nature.

(2) There is some evidence in animals, but little in humans, that fluoride can produce a change in the morphology of teeth and that the change could result in caries reduction.

PART II

METHOD

Selection of Samples

Recently erupted non-carious maxillary and mandibular first permanent molars were considered most suitable for study because:

(1) Studies which have been done on animal molars afford a basis for comparison.

(2) The molar offers a variety of measurements for study.

(3) In newly erupted molars the possibility of caries is reduced.

The communities of Wetaskiwin (population 5,540) and Camrose (population 7,708) were chosen for the study. Investigation of the fluoride content of the water supplies for the past seven years revealed that Wetaskiwin has had naturally-occurring fluoride in the amount of 1.0 to 2 ppm., while Camrose water has contained only traces (.01 ppm. or less) of fluoride (59).

Preliminary screening of all Grade 1 school children in both communities revealed that a sufficient number of samples could be found in each town despite the fact that there is a considerable population turnover even in small prairie towns.

In order to eliminate possible racial variation, no Negroes, North American Indians or Orientals were included. Parents of each child selected were questioned about their paternal and maternal racial backgrounds. The socio-economic status of each family was also investigated. The samples were then rated for racial

background and socio-economic status according to Blishen's method of scoring (60) (Tables 11, 12) to ascertain whether the communities were comparable on this basis. Races were classified as West European, East European and mixed.

Where possible one maxillary molar and one mandibular molar from each mouth was used for the study. Thirty-eight mandibular molars and forty-one maxillary molars from Camrose and forty-one mandibular molars and forty maxillary molars from Wetaskiwin, totalling one hundred and sixty teeth, were used for detailed study.

Impressions.--An impression technique was needed which would accurately reproduce fine detail, give maximum compression of gingival tissue and good penetration into embrasures and contact areas. A material with minimal dimensional change was also required because of the necessary time lapse between impression-taking and pouring of models. After consulting the literature, (61) (62) (63) (64) (65), and experimenting in the University of Alberta Dental Clinic, the technique decided upon involved the use of rubber base impression material in prefabricated sectional acrylic trays. (Fig. 6)

TABLE 11

DISTRIBUTION OF RACIAL BACKGROUNDS OF WETASKIWIN AND CAMROSE CHILDREN INCLUDED IN THE STUDY

	Wetaskiwin	Camrose
West European	38	37
East European	3	1
Mixed	2	4
Total	43	42

TABLE 12

OCCUPATIONS OF PARENTS RANKED AND GROUPED ACCORDING TO COMBINED STANDARD SCORES FOR INCOME AND YEARS OF SCHOOLING*

CLASS	SCORE	WETASKIWIN	CAMROSE
I	82.5		1
	78.8	2	1
II	69.8		1
	65.8		1
	63.0		
	62.2	2	
	61.8	1	
	57.6	1	
	57.0	3	8
III	56.9	1	
IV	51.2		1
V	50.2		2
	49.4	2	
	49.2	1	
	48.7	1	2
	48.2	2	1
	47.7		2
	47.5	1	
	47.2	4	2
	46.8		1
	46.5	1	
	45.9	1	
	45.6	8	1
	45.4		1
	45.2	1	
VI	45.0		3
	44.6	1	2
	44.4	1	1
	43.6	6	1
	43.2	2	2
VII	41.6		2
	41.4	1	1
	40.8		4
	38.8		1
TOTAL		43	42

*According to Blishen (60)

The tooth being prepared for the impression was scrubbed with three per cent hydrogen peroxide. The child's mouth was flushed with "Sterisol" solution and the tooth was dried with compressed air. An initial impression was taken with heavy bodied rubber base material.* This impression was removed when set. It was dried and lined with light bodied rubber base impression material. The same material was applied to the tooth and worked into the pits and fissures with an explorer. The previously loaded tray was then reseated on the tooth and the impression was taken under pressure.

Models.--Models were poured in "Vel-Mix" die stone. Powder and water were measured consistently, mixed in a mechanical spatulator and vibrated into the impressions. The models were trimmed with the base parallel to the occlusal surface, and the sides and ends perpendicular to the base. All excess material was removed to facilitate mounting.

The accuracy of the technique was tested by taking five impressions of the same tooth in the same mouth, pouring the models in "Vel-Mix" three to six hours later (comparable to the time lapse during the study); then measuring mesiodistal and buccolingual diameters of the models, using a Mitutoyo-Vernier caliper accurate to 0.05 mm. (Fig. 7). These measurements were taken alternately without consulting previous figures.

The models were trimmed so that the Mitutoyo-Vernier

*Kerr's Permalastic

Fig. 6.--Rubber base impression in sectional acrylic tray.

caliper could encompass the tooth. The average deviation from the mean of the ten measurements was less than one per cent. This figure compares with the average measuring error calculated from multiple blind measurements of the models used in the study. One can therefore conclude that the technique for taking the impressions and pouring the models was accurate. One can also conclude that the personal measuring error was well within acceptable limits. Since this error was distributed throughout both groups, it does not affect the validity of the findings relative to morphological differences between the two groups of teeth.

Direct measurements of models.--The following direct measurements were made:

Mandibular Molars

(1) mesiodistal diameter
(2) buccolingual diameter
(3) height of the mesiobuccal cusp above the gingival margin
(4) separate mesiodistal and buccolingual measurements of molars of male and female subjects

Maxillary Molars

(1) mesiodistal diameter
(2) buccolingual diameter
(3) height of the mesiobuccal cusp above the gingival margin
(4) separate mesiodistal and buccolingual measurements of molars of male and female subjects

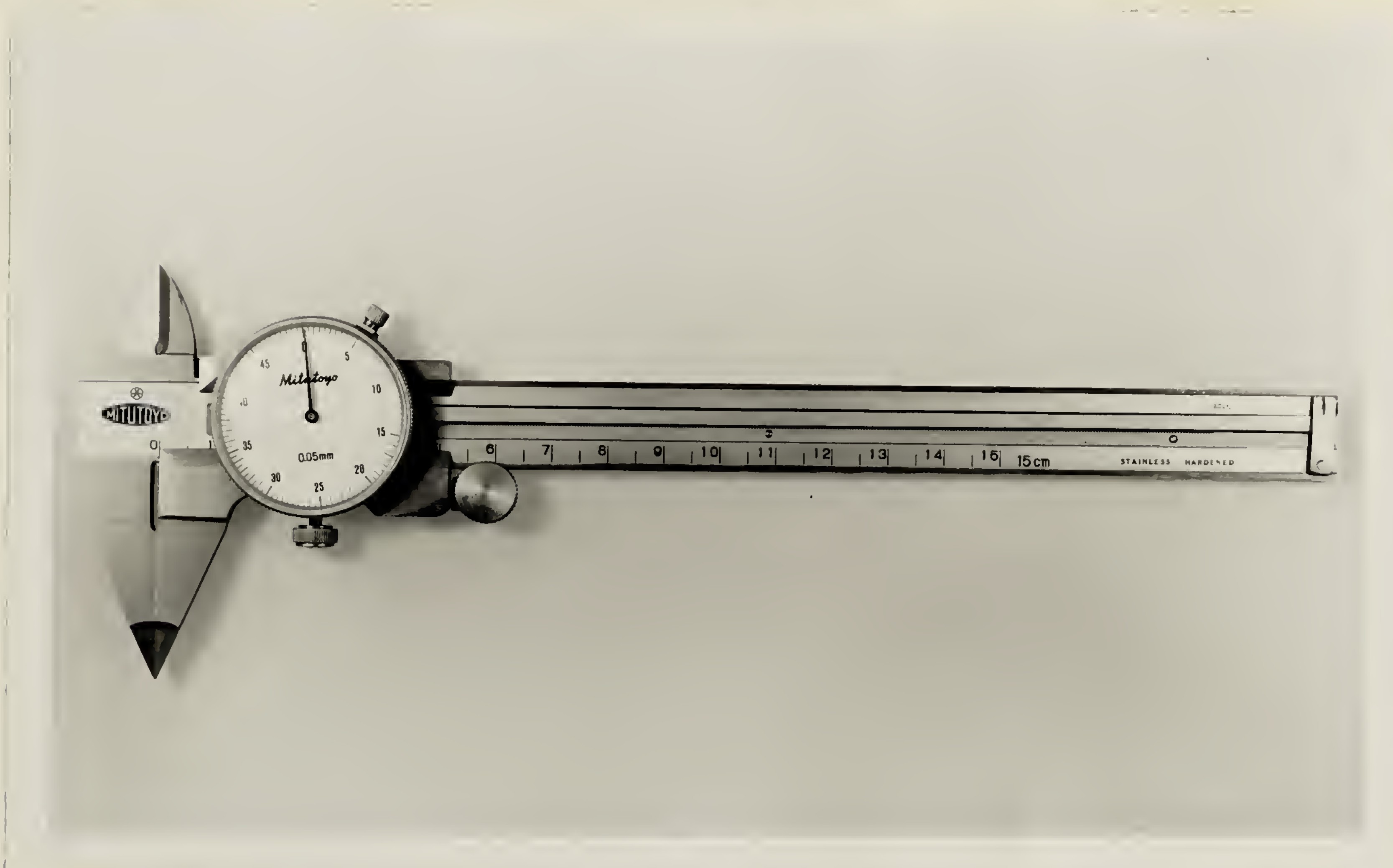


Fig. 7.--Mitutoyo-Vernier caliper used for measuring models and photographs.

Grinding of models.--A faceting machine, commonly used for cutting semi-precious stones, (Fig. 8) was used for sectioning models. Vertical, horizontal and rotational adjustments were possible with this machine, so that all models could be orientated in the same way for grinding and for photographing at each point. The model was mounted at its mesial end with special sealing jeweller's wax. The occlusal surface of each model was painted with black India ink before sectioning to accentuate the plane surface of sections in the photographs.

After each cut the arm of the machine bearing the model was rotated to facilitate photographing the model. The plane surface of the model was positioned parallel to the lens surface.

Fig. 8.--Faceting machine used for grinding models.

After each photograph the model was returned for the next step in grinding. The plane surface of each section was labelled with a code which was interpreted after all measurements were completed.

The following sections were made of maxillary molars:

(a) from the tip of the distolingual cusp to the tip of the distobuccal cusp.

(b) from the tip of the distobuccal cusp to the tip of the mesiolingual cusp.

(c) from the tip of the mesiobuccal cusp to the tip of the mesiolingual cusp.

The lower molars were sectioned as follows:

(a) from the tip of the distolingual cusp to the tip of the buccal (middle) cusp.

(b) from the tip of the mesiolingual cusp to the tip of the buccal (middle) cusp.

(c) from the tip of the mesiolingual cusp to the tip of the mesiobuccal cusp.

Photographic equipment and photographic procedure.--The equipment used for photographing models is shown in Fig. 9. An Asahi Pentax camera with extension tubes was used with an electronic ringlight. The camera stand was set so that all exposures could be made with the camera in the same relation to each model. Focusing was accomplished by slight adjustment of the camera forward or backward. Panatomic X film was exposed at F 16, and enlarged

prints (approximately ten times) were produced on Kodak N-4 Resisto-rapid non-shrink paper, using a standardized enlarger setting. Measurements of enlarged photographs were compared with direct measurements to check the consistency of the enlarging.

Before sectioning, the occlusal surface of each molar was photographed for observation of occlusal pattern and for comparison with direct measurements (Fig. 10). Because all parts of the teeth were not in sharp focus in the occlusal photographs, it was decided that only the direct measurements would be used for mesiodistal and buccolingual diameters. The enlarged prints were coded and the code interpreted after observations had been made.

An enlarged print was made of each plane surface during sectioning. (Fig. 11)

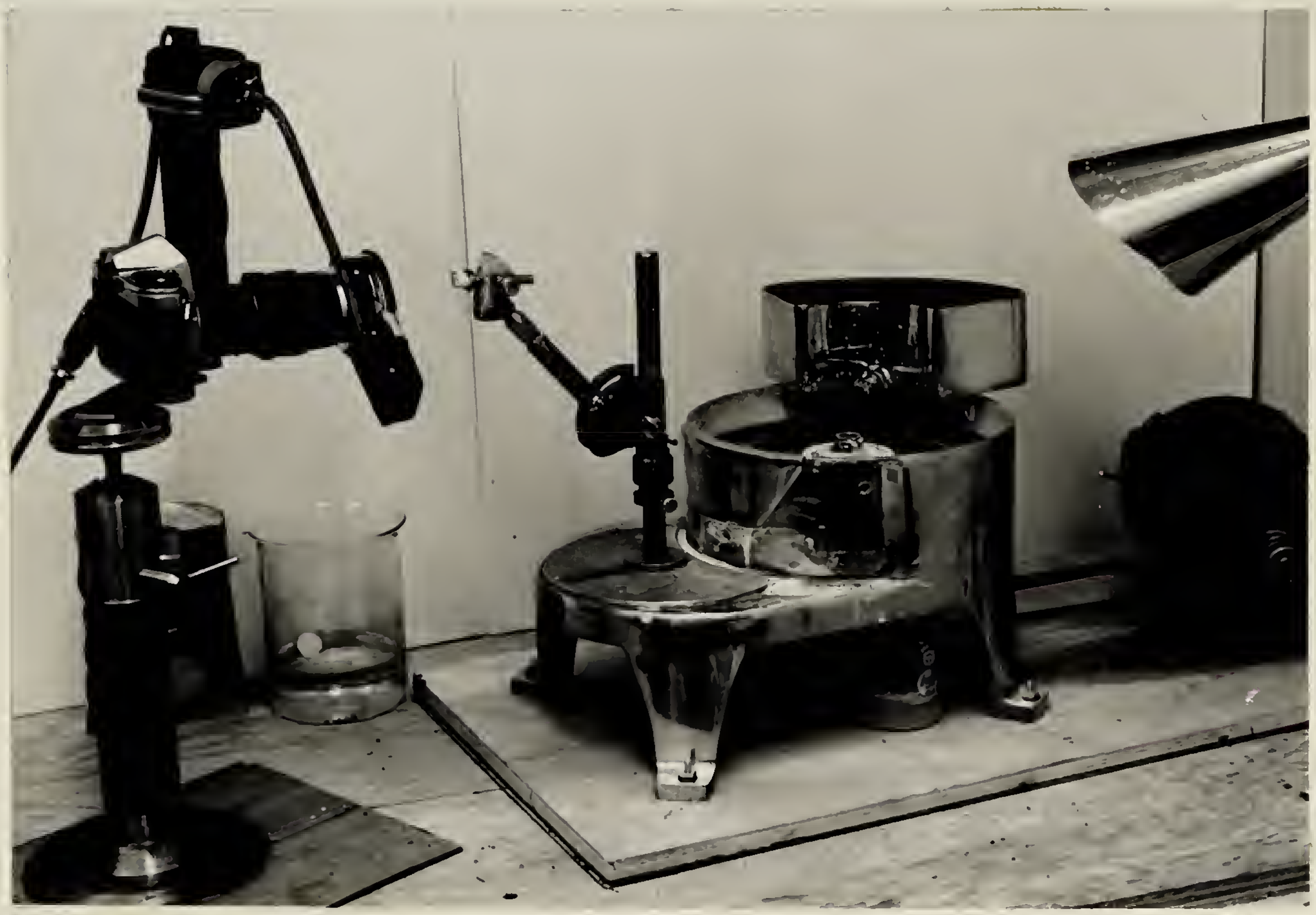


Fig. 9.--Equipment used for photographing models.

Fig. 10.--Enlarged print of the occlusal surface of a molar cast.

Measurement of photographs.--Fig. 12 illustrates the method of measuring the mesiodistal and buccolingual diameters of the enlarged occlusal photographs. A parallel rule was used to determine the greatest diameter.

The occlusal photographs were examined to detect:

(1) Dryopithecus patterns in the mandibular molars, i.e. y pattern, + pattern, or X pattern.

(2) The presence of Carabelli's cusp on maxillary molars. The width of Carabelli's cusp was measured from the groove to the outside contour of the cusp.

Fig. 11.--Enlarged print of a sectioned molar cast.

The following measurements were taken from the photograph of each section:

(1) The depth of the fossa, determined by measuring the perpendicular from the deepest point in the fissure to a line joining the cusp tips (Fig. 13).

(2) The angle formed between lines drawn along the slopes of the cusps in the basal third of the groove. (Fig. 13).

(3) The distance between the cusp tips (Fig. 13).

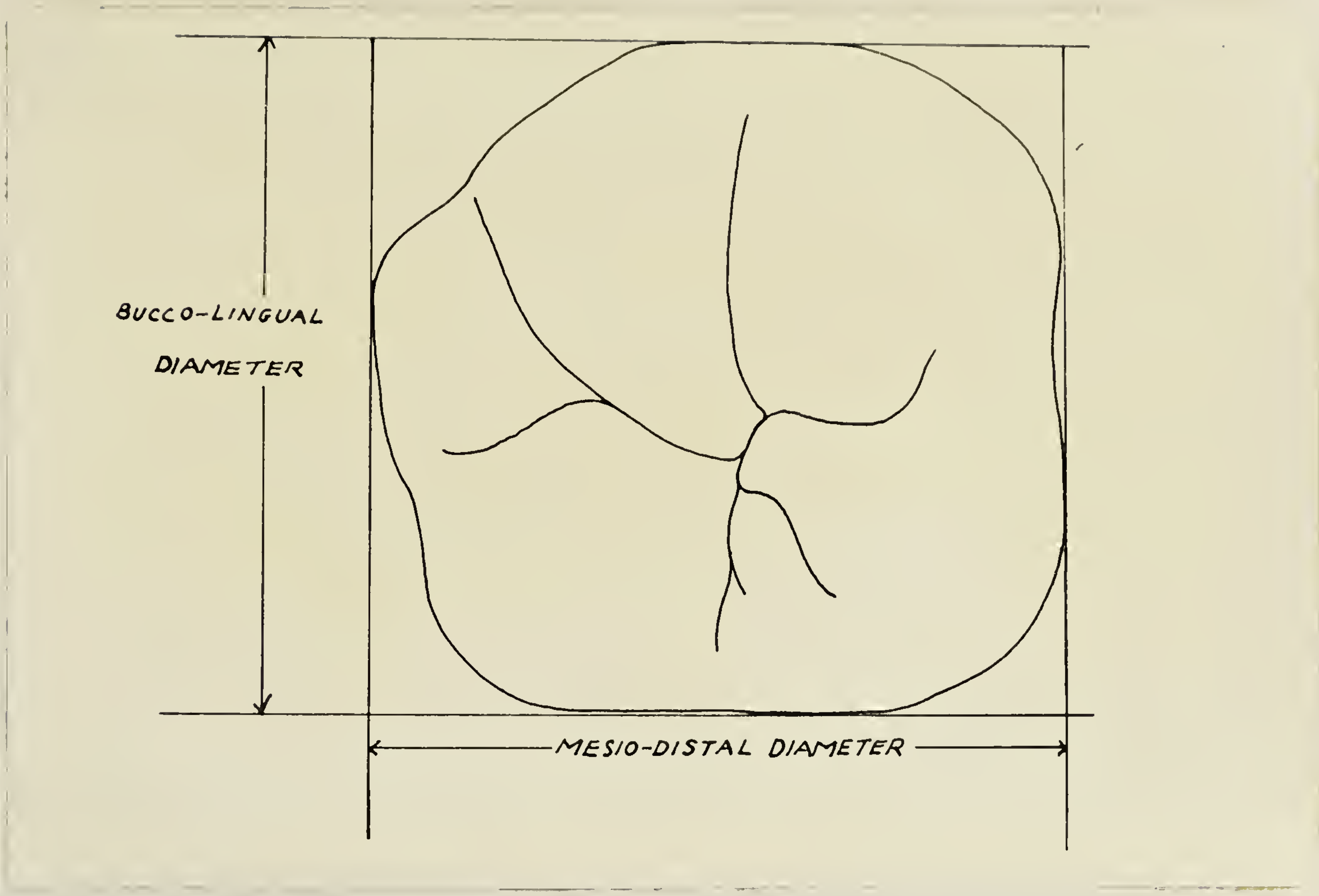


Fig. 12.--Method of measuring enlarged photographs of the occlusal surface.

The shape of the base of the fissure was judged to be round, deeply fissured, or V-shaped. Only occasionally was the shape not specifically classifiable.

Figure 13 illustrates the method of measuring the sectioned teeth. The angles were measured with a "spirule" (Fig. 14).

The outline of the enlarged photograph of each section was traced, as shown in Figures 15 to 26, Appendix A.

Heights and weights of all children in the study were recorded.

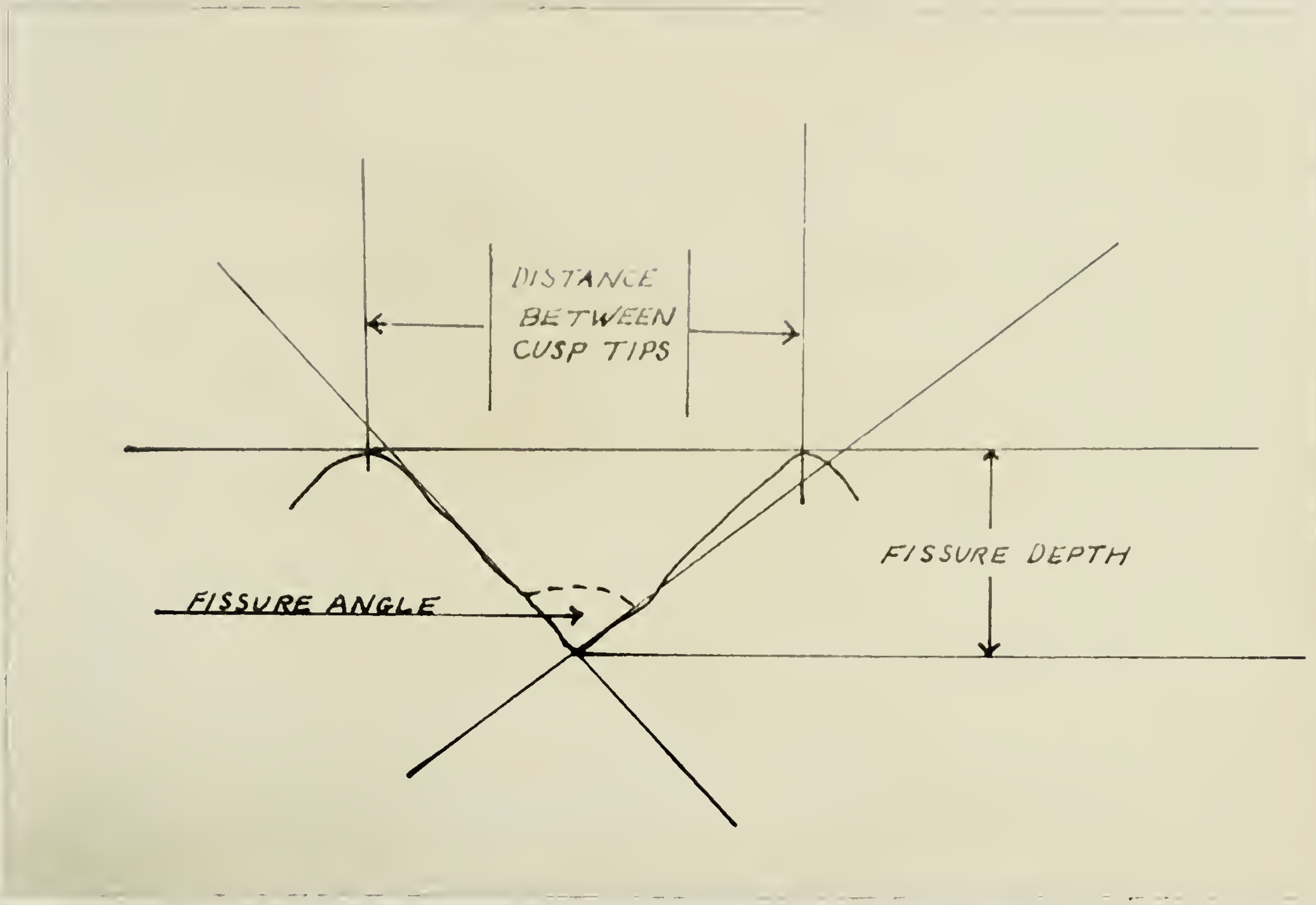


Fig. 13.--Illustration of measurements taken from the photographs of sectioned molars.

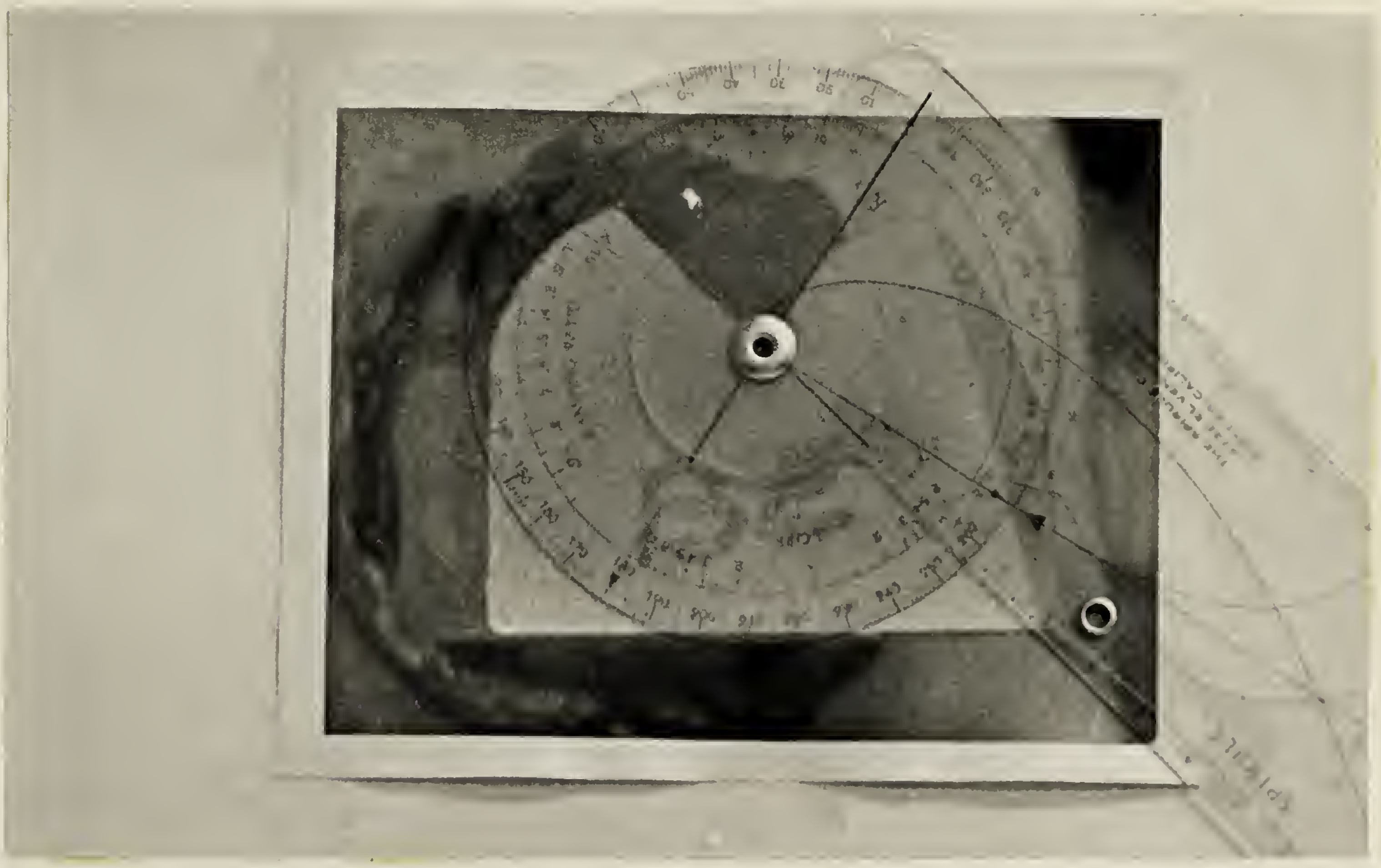


Fig. 14.--Illustration of the method of measurement of fissure angles using a "spirule".

PART III

RESULTS

Table 13 shows the analysis of the direct measurement of molar casts to determine mesiodistal and buccolingual diameters. Although the dimensions of maxillary and mandibular molars in the optimum fluoride sample are consistently greater than those in the low fluoride sample, only the mesiodistal diameter of mandibular molars in the optimum fluoride group is significantly greater. There appears to be no difference between the two groups in the state of eruption, determined by measuring the height of the tip of the mesiobuccal cusp above the gingival margin.

The mesiodistal and buccolingual measurements of the molars of males and females were subjected to a Chi-square test for independence. The test revealed that the size of human molars in this study was independent of sex.

Only two occlusal patterns could be recognized in the mandibular molars, namely the Y5 Dryopithecus pattern and the +4 pattern. Four-cusped mandibular molars appeared more frequently in the low fluoride sample, as shown in Table 14. It was discovered that the mean mesiodistal diameter of four-cusped mandibular molars

(9.91 mm.) was less than that of five-cusped mandibular molars (10.60 mm.). The mean mesiodistal diameter of maxillary molars from the same mouths as the four-cusped mandibular molars (10.03 mm.) was also found to be smaller than the mean mesiodistal diameter for the total sample (10.32 mm.).

TABLE 13

COMPARISON OF DIRECT MEASUREMENTS OF MAXILLARY FIRST PERMANENT MOLARS AND MANDIBULAR FIRST PERMANENT MOLARS FROM A COMMUNITY WITH LOW LEVELS OF WATER-BORNE FLUORIDES AND A COMMUNITY WITH OPTIMUM LEVELS OF WATER-BORNE FLUORIDES

Maxillary Molars	Camrose n=41		Wetaskiwin n=40		Difference Between Means	"t" test P
	Mean	Range	Mean	Range		
Mesiodistal Diameter	10.32 SE=0.078	9.45-11.30	10.44 SE=0.010	9.13-11.97	0.12 SE=0.126	0.34
Buccolingual Diameter	10.87 SE=0.084	9.90-12.58	10.88 SE=0.094	9.90-12.21	0.01 SE=0.126	0.93
Height of Mesiobuccal Cusp above Gingival Margin	3.96 SE=0.100	2.46-5.65	4.04 SE=0.100	2.37-5.45	0.08 SE=0.141	0.57

Mandibular Molars	Camrose n=38		Wetaskiwin n=41		Difference Between Means	"t" test P
	Mean	Range	Mean	Range		
Mesiodistal Diameter	10.39 SE=0.118	9.00-12.07	10.72 SE=0.100	9.10-11.87	0.33 SE=0.154	0.05*
Buccolingual Diameter	10.14 SE=0.100	8.95-11.71	10.26 SE=0.077	9.40-11.20	0.12 SE=0.126	0.44
Height of Mesiobuccal Cusp above Gingival Margin	4.64 SE=0.141	2.47-5.84	4.59 SE=0.122	2.51-5.83	0.05 SE=0.187	0.79

* statistically significant

TABLE 14

COMPARISON OF OCCLUSAL PATTERNS OF MANDIBULAR MOLARS FROM LOW LEVELS OF WATER-BORNE FLUORIDE AND OPTIMUM LEVELS OF WATER-BORNE FLUORIDES

Camrose N=38					Wetaskiwin N=41				
Dryopithecus Pattern			Five Cusps	Four Cusps	Dryopithecus Pattern			Five Cusps	Four Cusps
Y	+	X*			Y	+	X*		
26	12		26	12	39	2		39	2
68.42%	31.58%		68.42%	31.58%	95.12%	4.88%		95.12%	4.88%

*X patterns were not discernible in the sample.

Carabelli's cusps appeared more frequently on maxillary molars in the optimum fluoride group and tended to be larger than those in the low fluoride group. However, the difference in size did not reach significance, as shown in Table 15.

TABLE 15

INCIDENCE AND SIZE OF CARABELLI'S CUSP FROM LOW LEVELS OF WATER-BORNE FLUORIDES AND OPTIMUM LEVELS OF WATER-BORNE FLUORIDES

Incidence		Mean Size		Difference Between Means	"t" test P
n=43 Camrose	n=41 Wetaskiwin	Camrose	Wetaskiwin		
29	31	11.54	12.13	0.59	0.60
67.44%	75.61%	SE=0.812	SE=0.781	SE=1.126	

The analysis of the measurements of enlarged photographs of sectioned maxillary and mandibular first permanent molars appears in Tables 16 and 17. With one exception (Section B, maxillary molars) the depth of fissures was greater in the non-fluoride sample.

TABLE 16

COMPARISON OF MEASUREMENTS OF ENLARGED PHOTOGRAPHS OF SECTIONED MAXILLARY MOLARS

SECTION A	Camrose n=41	Wetaskiwin n=40	Difference Between Means	"t" test P
Depth of fissure	25.14 SE=0.360	24.02 SE=0.374	1.12 SE=0.519	0.05*
Angle at base of fissure	80.00 SE=1.50	83.15 SE=1.99	3.15 SE=2.498	0.21
Distance between cusp tips	60.31 SE=0.754	60.21 SE=2.98	0.10 SE=1.208	NS
SECTION B	n=41	n=40		
Depth of fissure	20.72 SE=0.469	21.48 SE=0.489	0.76 SE=0.678	0.27
Angle at base of fissure	100.95 SE=1.46	103.60 SE=1.70	2.65 SE=2.242	0.24
Distance between cusp tips	62.77 SE=0.92	62.81 SE=0.909	0.04 SE=1.292	NS
SECTION C	n=41	n=40		
Depth of fissure	24.74 SE=0.58	23.98 SE=0.600	0.76 SE=0.836	0.30
Angle at base of fissure	85.34 SE=0.583	88.73 SE=1.726	3.39 SE=3.605	0.35
Distance between cusp tips	59.81 SE=0.700	59.87 SE=0.883	0.06 SE=1.126	NS

*statistically significant NS - not significant

SECTION A - cut from distolingual cusp tip to distobuccal cusp tip

SECTION B - cut from distobuccal cusp tip to mesiolingual cusp tip

SECTION C - cut from mesiolingual cusp tip to mesiobuccal cusp tip

TABLE 17

COMPARISON OF MEASUREMENTS OF ENLARGED PHOTOGRAPHS OF SECTIONED MANDIBULAR MOLARS

SECTION A	Camrose n=36	Wetaskiwin n=29	Difference Between Means	"t" test P
Depth of fissure	22.28 SE=0.700	21.01 SE=0.50	1.27 SE=0.80	0.13
Angle at base of fissure	84.25 SE=3.03	90.10 SE=2.709	5.85 SE=40.62	0.15
Distance between cusp tips	54.16 SE=1.840	56.89 SE=1.005	2.27 SE=2.104	0.20
SECTION B	n=38	n=30		
Depth of fissure	26.08 SE=0.509	22.94 SE=0.608	3.14 SE=0.793	0.001*
Angle at base of fissure	87.82 SE=2.190	94.36 SE=2.116	6.54 SE=3.048	0.03*
Distance between cusp tips	67.72 SE=0.979	68.17 SE=0.959	0.45 SE=1.371	0.74
SECTION C	n=38	n=42		
Depth of fissure	18.31 SE=0.398	17.32 SE=1.109	0.89 SE=0.531	0.10
Angle at base of fissure	88.58 SE=1.113	93.40 SE=2.383	4.82 SE=2.630	0.07
Distance between cusp tips	50.38 SE=0.728	50.83 SE=0.812	0.45 SE=1.090	0.71

SECTION A - cut from distolingual cusp tip to buccal (middle) cusp tip

SECTION B - cut from mesiolingual cusp tip to buccal (middle) cusp tip

SECTION C - cut from mesiolingual cusp tip to mesiobuccal cusp tip

* statistically significant

In two of the six sections this difference was statistically significant. The angles at the base of the fissures were consistently smaller in the low fluoride sample, but the difference reached statistical significance in only one group. There appeared to be a trend toward a smaller distance between cusp tips in the low fluoride group, but none of the differences approached statistical significance.

Table 18 shows the classification of the shape of the base of fissures. Although a statistically valid analysis is difficult from subjective observations, one might say that there is a tendency toward more V-shaped grooves in the fluoride group and toward more grooves with a rounded base in the low fluoride group. Deeply-fissured grooves appear to be fairly evenly distributed between the two groups.

Average birth weights of the two groups of children were essentially the same. (Camrose - 3.57 kg., Wetaskiwin 3.65 kg.) Weights and heights of the children at the time of school registration were also compared. The average weight of the low fluoride group (48.8 lbs.) exceeded that of the optimum fluoride group (47.9 lbs.) by 0.9 pounds, whereas the average height of the optimum fluoride group (46.5 in.) was greater than that of the low fluoride group (44.03 in.) by 2.47 inches. In the light of documented evidence, related to the effects of fluoride on bone and on body weight, (68) (69) these differences can be disregarded.

TABLE 18

COMPARISON OF THE SHAPE OF THE BASE OF FISSURES FROM LOW LEVELS OF WATER-BORNE FLUORIDES AND OPTIMUM LEVELS OF WATER-BORNE FLUORIDES

	Camrose					Wetaskiwin				
Maxillary Molars*	N	R	D	V	OTHER	N	R	D	V	OTHER
SECTION A	41	14 34.15%	5 12.19%	22 53.66%	0	40	12 30.00%	9 22.50%	19 47.50%	0
SECTION B	41	26 63.42%	2 4.88%	13 31.70%	0	40	22 55.00%	1 2.50%	17 42.50%	0
SECTION C	41	15 36.58%	7 17.08%	19 46.34%	0	40	8 20.00%	7 17.50%	25 62.50%	0
Mandibular Molars**	N	R	D	V	OTHER	N	R	D	V	OTHER
SECTION A	36	14 38.89%	9 25.00%	12 33.33%	1 2.78%	29	10 34.48%	3 10.34%	15 51.73%	1 3.45
SECTION B	38	16 42.11%	6 15.79%	11 28.95%	5 13.15%	30	14 46.67%	5 16.67%	7 23.33%	4 13.33
SECTION C	38	20 52.63%	10 26.32%	8 21.05%	0	42	13 30.95%	9 21.43%	18 42.86%	2 4.76%

N = total number of teeth; R = rounded; D = deeply fissured; V = V-shaped; OTHER = not classifiable as R, D, or V.

*SECTION A - cut from distolingual cusp tip to distobuccal cusp tip
SECTION B - cut from distobuccal cusp tip to mesiolingual cusp tip
SECTION C - cut from mesiolingual cusp tip to mesiobuccal cusp tip
**SECTION A - cut from distolingual cusp tip to buccal (middle) cusp tip
SECTION B - cut from mesiolingual cusp tip to buccal (middle) cusp tip
SECTION C - cut from mesiolingual cusp tip to mesiobuccal cusp tip

PART IV

DISCUSSION

The trend toward deeper fissures and smaller angles between the cusps of the teeth in the low fluoride group agrees with the findings and theories of Paynter and Grainger, (38), Kruger (30) (39) (45) and Cooper and Ludwig (58) in both animal and human studies. A tooth with deep fissures and acute intercuspal angles should theoretically be more susceptible to caries than one with shallower fissures and more obtuse intercuspal angles.

The trend toward wider spacing of cusp tips in the teeth of the optimum fluoride sample would seem to be consistent with the larger intercuspal angles and with the preponderance of V-shaped fissures in this group.

Teeth with more divergent cusps might reasonably be expected to have greater buccolingual diameters. Although the differences were not statistically significant, the mean buccolingual diameters of both maxillary and mandibular molars in the optimum fluoride sample were consistently greater than the mean buccolingual diameters of molars in the low fluoride sample. The same trend appeared in the measurements of mesiodistal diameters. The latter difference reached significance in the mandibular molars.

Examination of occlusal patterns of mandibular molars revealed that nearly thirty-two per cent of the low fluoride sample had four cusps, whereas approximately five per cent of the optimum fluoride sample had four cusps. The mean mesiodistal diameter of

the four-cusped molars was found to be smaller than the mean mesiodistal measurement of five-cusped molars. These findings agree with those of Dahlberg (17) in his study of the mandibular molars of Melanesian dentitions. Measurement of mesiodistal diameters of maxillary molars from the same mouths as the four-cusped mandibular molars revealed that these maxillary molars were also smaller than the average mesiodistal diameters of all maxillary molars. One can only conclude that the individuals with four-cusped mandibular molars have small teeth regardless of the number of cusps. Further study of a large sample with a pure racial background might provide valuable information about the incidence and size of four-cusped and five-cusped mandibular molars. Further clarification of the relationship of these different molar forms would also provide a more stable basis for future studies of tooth morphology as it relates to fluoride ingestion or in fact to other trace elements.

Although the racial origins of the groups in this study appeared to be homogeneous, the background of any Caucasian population is very difficult to assess accurately. This important variable could be eliminated if a similar study of a much larger sample were carried out on a population known to be of a pure strain. Such a sample might be found amongst Eskimos, East Indians or some of the more isolated Negro populations.

It is beyond the scope of this study to attempt to explain

why tooth morphology may be altered by fluoride ingestion. Some of the theories have been covered quite thoroughly in the review of the literature.

Theories relating tooth size to the crystallography of hydroxy apatite or fluorapatite do not seem justified in view of the present state of knowledge of crystallography. Neuman and Neuman (66), reviewing the crystallography of hydroxy apatite, say:

> The task is not easy, as the very name "apatite" indicates. Coined by Werner in 1790, the term is derived from the Greek word meaning "to deceive". This class of minerals has lived up to its name, deceiving and confusing minerologists, as it has chemists, throughout the years. It is difficult to attain a clear-cut comprehension of the crystallography of hydroxy apatite when the minerologists themselves do not agree on rather fundamental interpretations.

The same authors, discussing improvements in electron microscopes, say:

> . . . the investigator can at last dream of probing into the inner structure of the individual crystal! Surely before many years have passed, there will be final answers concerning the size, shape and variations in crystal morphology. . . At the present time, much of the electron-microscope findings on bone structure can be considered the fumbling beginnings of a new science.

Regarding the effect of toxic doses of fluoride on bone, Roholm (67) conducted post-mortem studies on bones of cryolite workers and found various parts of bones were chalky-white with irregular surfaces, and they were greatly increased in weight. Paynter and Grainger (38) found that rats, fed 12 ppm. fluoride, had smaller molars but experienced an increase in body weight. One wonders if the size and weight of the bones might have contributed

to the increase in body weight.

The use of the human first permanent molar in this study might be questioned because its development commences at about four months in utero. However, the studies of Kruger (39) (45) and Paynter (52) suggest that the critical period for effecting changes in the morphology of rat molars is the time just before and during hard tissue formation. In human first permanent molars, according to Christensen et al (70), initial calcification begins in the tip of the cusps between twenty-eight and thirty-two weeks in utero.

The water intake of infants might also be questioned with regard to the fluoride available during the development of the first permanent molar. McPhail and Zacherl (71) found that water intake per pound of body weight in the various age groups in Edmonton, Alberta, children was as follows:

Under one year	0.618 oz.
One to two years	0.333 oz.
Three to four years	0.381 oz.
Five to six years	0.375 oz.
Seven to eight years	0.362 oz.
Nine to ten years	0.360 oz.

Other similar studies confirm these results. It would therefore appear that water intake during the period of first permanent molar development is adequate.

It might be suggested that bicuspid or second permanent

molars should have been studied. Investigation of teeth other than first permanent molars should be undertaken, but in this particular study it would have been impossible to obtain enough subjects who had been lifetime residents in the two communities.

Although one might assume that morphological differences in the teeth in this study are a result of the difference in fluoride levels, the possibility of the effect of other trace elements should be recognized. One major difference in the water supplies of Camrose and Wetaskiwin other than fluoride is the hardness. Wetaskiwin water is exceptionally soft (72) whereas Camrose water has always been in the moderate to high hardness range. During the period 1957-58 when the first permanent molars used in this study were forming, the hardness of Camrose water was found to be 343.4, 196.7, and 288 p.p.m. when individual tests were run during February 1957, July 1957, and December 1958 respectively. Unpublished data on caries incidence in Camrose and Wetaskiwin show remarkably low caries experience in Wetaskiwin in conjunction with a low hardness factor in the drinking water (73). Studies which have attempted to relate fluoride levels, water hardness and caries incidence (74) have shown widely varying results. Consequently, no positive statement can be made relative to fluoride levels, water hardness and caries or tooth morphology.

The use of photogrammetry for mapping and measuring tooth topography may permit greater scope in future studies of tooth morphology. This method was contemplated during the early stages of the present study, but financial, technical and time considerations made its use impossible.

PART V

CONCLUSIONS

The differences in tooth morphology between the optimum fluoride group and the low fluoride group observed in this study were:

(1) The molars from the low fluoride group were smaller mesiodistally and buccolingually than the molars from the optimum fluoride group. The difference in mesiodistal diameter of mandibular molars was statistically significant.

(2) There was no difference in the state of eruption of the two groups, determined by measuring the height of the mesio-buccal cusp above the gingival margin.

(3) Fissures in the low fluoride group were deeper than those in the optimum fluoride group.

(4) The intercuspal angles were more acute in the low fluoride group than in the optimum fluoride group.

(5) The distance between cusp tips, measured on each section, appeared greater in the optimum fluoride group.

(6) The various shapes at the bases of fissures were fairly evenly distributed throughout the two groups of molars.

(7) Carabelli's cusp occurred more frequently and was larger (but not significantly so) in the optimum fluoride group.

(8) Four-cusped mandibular molars with occlusal patterns of the + type occurred more frequently in the low fluoride sample.

The findings of this study are consistent with the fact that teeth which have developed under conditions of optimum fluoride levels are resistant to dental caries.

Further investigations of a similar nature on large samples of pure racial strains would be justified.

APPENDIX A

COMPLETE TABLES OF RAW DATA

USED IN ANALYSIS

TABLE 19

DIRECT MEASUREMENTS OF CAMROSE MAXILLARY MOLARS

	Right	Left	Sex	Mesiodistal Diameter mm.	Buccolingual Diameter mm.	Ht of M-B Cusp. Cusp Above Gingival Margin mm.
		x	M	10.90	11.34	3.80
	x		M	10.96	12.58	4.42
		x	M	10.10	10.34	3.22
	x		F	9.59	10.76	3.14
	x		F	10.26	10.95	3.77
	x		M	9.45	10.04	3.61
	x		M	10.38	11.51	4.24
	x		F	9.91	9.90	3.55
	x		F	9.66	10.32	3.75
		x	F	10.94	11.26	4.62
	x		M	10.73	11.45	4.10
	x		M	10.00	11.10	4.45
	x		M	10.52	10.75	3.85
		x	M	10.54	10.01	3.26
	x		F	9.56	11.03	5.65
		x	M	9.95	10.87	4.40
	x		M	10.78	10.65	3.71
		x	F	10.25	11.38	4.26
	x		M	10.24	10.87	3.55
	x		F	9.05	10.37	2.46
	x		F	10.44	11.06	4.30
	x		F	10.78	10.42	3.24
	x		M	11.00	10.66	3.00
	x		F	11.45	11.31	4.22
		x	M	10.43	11.20	4.84
	x		F	10.13	10.04	4.64
	x		M	10.00	10.98	4.90
		x	F	10.16	10.33	4.13
	x		M	10.40	10.76	4.30
	x		M	10.40	10.91	3.59
		x	F	11.47	10.82	4.55
	x		F	10.42	10.94	4.54
	x		M	10.28	10.87	3.58
		x	M	11.30	10.77	3.92
	x		M	9.83	10.67	3.74
	x		M	9.77	11.04	4.30
	x		M	10.53	11.86	4.06
	x		M	10.45	11.00	4.08
		x	F	10.10	11.04	3.62
	x		M	9.90	11.13	4.21
	x		M	9.66	9.95	2.75
Total: 41	30	11	25M 16F	423.30	445.84	161.32
Mean:				10.32	10.87	3.96
Mean Female				10.40	10.74	
Mean Male				10.34	10.96	

TABLE 20

DIRECT MEASUREMENTS OF METASKIN IN MAXILLARY MOLARS

	Right	Left	Sex	Mesiodistal Diameter mm.	Buccolingual Diameter mm.	Ht of M-B Cusp. Cusp. Above Cingival
	x		M	9.75	10.77	3.70
	x		M	10.21	10.36	2.95
	x		M	10.05	10.67	4.35
	x		M	10.00	10.38	3.40
	x		M	11.39	10.98	4.40
	x		F	9.87	10.46	3.52
	x		F	10.15	10.95	3.36
	x		M	10.74	12.21	5.25
	x		M	11.06	10.51	4.74
	x		F	9.58	11.23	4.25
		x	F	10.26	10.35	3.22
	x		F	10.90	11.05	4.40
	x		M	10.60	10.70	4.00
		x	F	9.95	11.10	4.26
	x		M	10.61	11.46	3.95
	x		M	9.88	10.25	2.37
		x	F	9.56	10.51	3.75
	x		F	11.22	11.46	4.41
	x		M	11.00	11.45	4.31
	x		F	10.19	10.11	4.23
	x		F	11.16	11.55	4.52
	x		F	10.15	10.10	3.98
		x	M	11.20	11.51	5.45
	x		M	10.20	10.46	4.25
	x		F	10.82	12.00	4.00
		x	F	10.71	10.70	3.31
	x		F	10.00	10.75	4.56
	x		M	11.67	12.01	5.21
	x		M	10.20	10.20	3.75
	x		M	11.97	11.36	4.09
	x		M	10.80	11.34	4.00
	x		F	9.13	9.91	3.40
	x		M	10.35	10.94	3.85
	x		F	10.57	10.28	3.51
	x		F	10.00	10.48	3.83
	x		M	9.65	10.44	3.80
	x		M	11.49	11.61	4.68
		x	M	9.92	11.02	3.36
	x		F	10.97	11.30	4.38
	x		F	9.90	9.90	4.05
Total: 40	34	6	21M 19F	417.83	435.32	161.40
Mean:				10.44	10.88	4.04
Mean Female				10.26	10.75	
Mean Male				10.60	11.01	

TABLE 21

DIRECT MEASUREMENTS OF CAMROSE MANDIBULAR MOLARS

	Right	Left	Sex		Mesiodistal Diameter mm.	Buccolingual Diameter mm.	Ht of M-B Cusp. Above Gingival Margin mm.
		x	M		12.07	11.71	5.70
		x	M		10.91	10.04	2.84
		x		F	10.41	10.25	4.53
		x		F	10.54	9.46	2.47
		x	M		9.77	8.95	4.34
		x	M		9.98	11.21	4.65
		x		F	10.65	10.28	4.00
	x			F	9.27	9.75	4.29
		x		F	10.91	10.53	5.20
		x	M		10.65	9.86	5.10
	x		M		11.03	11.03	6.21
	x			F	10.37	10.54	5.84
	x		M		10.76	10.32	4.80
	x		M		11.47	10.36	4.07
	x			F	9.24	10.07	3.96
		x	M		10.06	10.16	5.47
		x	M		10.17	10.54	5.25
	x			F	9.51	9.41	3.61
		x		F	10.35	10.15	4.04
		x		F	11.00	9.64	4.02
		x	M		9.25	9.55	3.22
		x	M		10.63	10.05	5.42
		x		F	10.80	10.82	5.00
		x		F	10.83	9.80	4.83
		x	M		10.63	10.58	5.74
	x			F	9.52	9.04	3.65
	x		M		9.15	9.93	4.17
	x		M		10.82	10.65	5.25
	x			F	11.00	10.32	4.45
		x		F	10.11	10.14	5.50
		x	M		10.06	10.66	5.43
	x		M		11.64	10.91	4.30
		x	M		9.00	9.32	4.10
		x	M		10.05	9.36	4.60
		x	M		10.07	10.22	5.05
	x			F	10.86	10.15	5.57
		x	M		11.37	10.38	5.66
		x	M		9.77	9.12	3.46
Total: 38	13	25	22M	16F	394.68	385.28	176.39
Mean:					10.39	10.14	4.64
Mean Female					10.34	10.02	
Mean Male					10.42	10.22	

TABLE 22

DIRECT MEASUREMENTS OF WETASKIWIN MANDIBULAR MOLARS

	Right	Left	Sex	Mesiodistal Diameter mm.	Buccolingual Diameter mm.	Ht of M-B Cusp. Above Gingival Margin mm.
		x	M	10.55	10.20	5.11
		x	M	11.00	10.21	3.17
	x		F	9.92	9.57	2.51
		x	M	10.32	10.16	4.55
		x	M	9.60	9.76	3.57
		x	M	11.16	10.18	4.87
		x	F	10.38	10.10	4.73
		x	F	10.46	9.73	4.31
		x	M	11.46	11.07	6.15
	x		M	10.00	10.06	4.82
		x	F	10.60	10.50	5.00
		x	M	9.10	9.57	4.18
		x	F	10.61	10.89	5.30
		x	M	10.48	10.04	5.16
	x		F	10.47	10.48	3.80
		x	M	10.74	10.32	4.46
		x	M	10.08	9.77	3.16
	x		F	10.38	9.78	4.14
		x	F	11.16	10.44	4.41
		x	M	11.35	10.88	5.05
		x	F	10.00	9.98	5.75
		x	F	11.00	11.12	4.90
		x	F	10.14	9.57	3.81
	x		M	11.77	10.72	5.60
		x	M	11.38	9.65	5.25
		x	F	10.95	10.63	4.34
	x		F	11.15	10.58	3.45
		x	F	10.40	10.66	4.95
		x	M	11.28	11.20	5.54
		x	M	11.11	10.16	4.50
		x	M	11.86	10.77	4.96
		x	M	11.87	11.04	4.95
		x	F	10.08	9.88	4.10
		x	M	11.10	11.01	4.57
	x		F	10.34	9.85	4.57
		x	F	10.069	10.20	4.65
	x		M	10.70	9.56	3.35
		x	M	11.79	10.67	5.83
		x	M	10.93	9.90	5.21
		x	F	11.12	10.35	5.01
		x	M	10.48	9.40	4.00
Total: 41	8	33	23M 18F	439.40	420.59	188.00
Mean:				10.72	10.26	4.59
Mean Female				10.51	10.38	
Mean Male				10.87	10.27	

TABLE 23

SECTIONS OF CAMROSE MAXILLARY MOLARS FROM

DISTOLINGUAL CUSP TIP TO DISTOBUCCAL CUSP TIP

(N = 41)

Depth of Fissure mm.	Angle at base of Fissure (degrees)	Distance between cusp tips mm.	Shape of base of fissure		
			R*	D*	V*
24.41	72	58.70	x		
29.27	70	67.07		x	
24.96	82	61.71			x
23.51	84	65.65			x
24.91	85	63.55			x
29.17	64	55.21			x
23.96	72	61.56			x
28.15	65	59.75		x	
24.27	93	65.12	x		
25.34	93	59.40	x		
22.00	77	58.45	x		
24.38	82	64.40	x		
25.56	70	61.18			x
23.21	80	50.11		x	
27.14	81	59.54			x
29.00	67	56.71			x
28.66	76	57.75			x
20.34	90	56.50	x		
25.51	79	48.62			x
21.60	82	54.25			x
27.32	85	66.68			x
21.90	83	62.87			x
21.57	89	57.30			x
24.37	76	60.15	x		x
28.31	67	69.00			
26.55	69	57.03			x
25.84	83	60.14		x	
27.00	82	59.19			x
24.54	74	54.86	x		
22.76	70	53.97		x	
23.92	78	58.28			x
23.73	103	64.98	x		
22.58	97	58.10	x		
24.05	87	57.76	x		
27.96	83	61.76			x
23.45	81	59.81	x		
24.56	82	66.77	x		
29.47	73	57.55			x
21.06	105	64.64			x
26.91	74	69.06	x		
26.90	75	68.18			x
TOTAL 1030.60	3280	2473.31	14	5	22
MEAN 25.14	80	60.31			

*R - round *D - deeply fissured *V - V shaped C - other

TABLE 24

SECTIONS OF WETASKIWIN MAXILLARY MOLARS FROM DISTOLINGUAL CUSP TIP TO DISTOBUCCAL CUSP TIP

(N = 40)

Depth of Fissure mm.	Angle at base of Fissure (degrees)	Distance between cusp tips mm.	Shape of base of fissure		
			R*	D*	V*
23.80	77	58.92		x	
26.18	72	65.18			x
25.50	84	60.82			x
28.37	81	66.47	x		
25.74	64	53.90			x
28.42	64	50.80		x	
22.13	88	51.93	x		
23.91	84	52.25			x
24.60	61	53.55		x	
23.66	80	54.27		x	
22.37	78	56.90			x
21.66	80	57.64	x		
26.00	63	54.05		x	
23.37	90	60.97	x		
20.88	72	57.75			x
24.60	86	61.00			x
29.04	65	53.03			x
23.38	87	58.04	x		
20.46	106	73.36			x
21.70	105	59.43	x		
24.76	91	59.09			x
25.50	90	67.32			x
21.61	78	66.75		x	
17.74	106	57.27	x		
23.12	96	63.21	x		
23.38	84	53.14		x	
24.74	83	72.74		x	
26.80	68	59.64		x	
22.45	97	60.12	x		
24.30	83	66.63			x
21.00	108	60.16	x		
20.70	89	52.17	x		
23.33	96	63.96	x		
25.07	92	70.60			x
24.80	86	66.94			x
26.05	62	53.42			x
24.63	76	62.74			x
25.13	93	64.46			x
27.66	74	64.33			x
22.16	87	63.18			x
TOTAL 960.70	3326	2408.33	12	9	19
MEAN 24.02	83.15	60.21			

*R - round *D - deeply fissured *V - V shaped O - other

TABLE 25

SECTIONS OF CAMROSE MAXILLARY MOLARS FROM

DISTOBUCCAL CUSP TIP TO MESIOLINGUAL CUSP TIP

(N = 41)

	Depth of Fissure	Angle at base of Fissure	Distance between cusp tips	Shape of base of fissure			
				R*	D*	V*	O
	21.14	94	66.88	x			
	22.78	90	60.00		x		
	21.07	89	67.04		x		
	19.65	92	51.80	x			
	18.60	89	54.88	x			
	9.86	110	42.15			x	
	19.70	83	63.35	x			
	23.16	91	68.66			x	
	20.24	98	59.64	x			
	23.61	102	69.76			x	
	20.13	105	65.50			x	
	21.37	91	60.75	x			
	22.54	108	67.88	x			
	15.22	119	56.62	x			
	16.37	108	58.74	x			
	22.24	118	70.58			x	
	19.24	92	54.45			x	
	20.41	108	64.84	x			
	20.64	117	67.43	x			
	17.93	98	58.88	x			
	21.35	123	66.90	x			
	19.14	105	65.42			x	
	21.45	95	62.34			x	
	20.16	94	67.86	x			
	21.14	110	61.58			x	
	21.34	100	65.00	x			
	21.60	105	65.53	x			
	21.84	102	68.80	x			
	18.21	101	66.02	x			
	17.17	100	55.22	x			
	23.01	111	64.95	x			
	25.52	101	63.36			x	
	23.87	98	60.00			x	
	23.11	112	65.65	x			
	20.11	101	59.53		x		
	27.00	100	67.45			x	
	18.58	93	56.74	x			
	26.05	88	58.00	x			
	20.13	100	64.90			x	
	22.65	93	71.81	x			
	20.85	105	66.50	x			
TOTAL	849.68	4139	2573.39	26	2	13	0
MEAN	20.72	100.95	62.77				

*R - round *D - deeply fissured *V - V shaped * O - other

TABLE 26

SECTIONS OF WETASKIWIN MAXILLARY MOLARS FROM

DISTOBUCCAL CUSP TIP TO MESIOLINGUAL CUSP TIP

(N = 40)

Depth of Fissure		Angle at base of Fissure	Distance between cusp tips	Shape of base of fissure			
				R*	D*	V*	O
	23.08	88	57.31	x			
	18.21	110	63.43	x			
	16.11	103	62.21	x			
	24.31	89	66.82			x	
	21.90	88	61.15	x			
	19.50	116	70.73			x	
	20.98	117	56.23	x			
	22.27	100	68.91			x	
	21.54	90	55.02			x	
	23.54	108	62.38	x			
	18.34	118	62.73			x	
	19.01	108	59.16	x			
	20.40	105	56.41	x			
	23.75	96	63.41	x			
	19.66	115	61.55			x	
	17.00	118	63.75			x	
	24.30	89	60.60			x	
	17.25	109	53.10	x			
	15.95	92	52.24	x			
	26.00	109	71.15	x			
	21.30	99	63.21			x	
	23.00	111	61.38	x			
	20.72	88	57.65	x			
	25.06	77	53.20			x	
	21.18	100	67.46			x	
	22.77	99	63.71			x	
	21.11	118	64.60			x	
	25.24	88	64.57		x		
	19.70	115	61.23			x	
	20.86	107	68.60			x	
	19.35	111	68.84	x			
	18.81	112	69.80	x			
	18.00	114	73.77			x	
	23.71	97	49.80	x			
	23.00	116	74.45	x			
	17.76	111	59.45	x			
	24.74	108	63.57	x			
	21.25	99	68.18	x			
	22.64	105	64.18	x			
	21.11	101	63.74			x	
TOTAL	859.40	4144	2512.28	22	1	17	0
MEAN	21.48	103.6	62.81				

*R - round *D - deeply fissured *V - V shaped O - other

TABLE 27

SECTIONS OF CAMROSE MAXILLARY MOLARS FROM

MESIOLINGUAL CUSP TIP TO MESIOBUCCAL CUSP TIP

(N = 41)

Depth of Fissure	Angle at base of Fissure	Distance between cusp tips	Shape of base of fissure			
			R*	D*	V*	O
22.75	89	59.40			x	
24.35	100	59.71	x			
27.10	82	69.33			x	
22.28	104	55.28	x			
26.28	97	68.80			x	
24.86	95	64.05			x	
24.11	89	57.46			x	
23.11	67	52.45	x			
19.25	96	55.93	x			
31.91	64	57.90			x	
25.30	83	50.52		x		
31.64	71	56.00		x		
25.70	83	57.81			x	
24.85	90	59.56		x		
26.36	98	64.27			x	
28.14	69	60.54			x	
25.13	84	61.00			x	
18.72	108	67.20			x	
16.76	97	52.90	x			
26.74	81	62.11			x	
24.58	69	64.11	x			
22.25	89	54.68			x	
28.26	70	62.03		x		
27.84	62	57.66		x		
21.68	109	63.72	x			
26.90	96	66.60	x			
22.15	107	54.15	x			
19.28	100	53.04			x	
20.25	73	58.80	x			
22.60	104	62.58			x	
28.85	65	55.00			x	
26.10	86	56.20			x	
21.36	112	63.50		x		
26.31	82	61.70			x	
19.00	117	61.68	x			
32.55	52	64.30		x		
23.10	91	54.00			x	
21.75	90	59.54	x			
23.14	102	65.68	x			
26.00	79	60.45	x			
25.10	87	60.70	x			
TOTAL 1014.29	3499	2452.34	15	7	19	0
MEAN 24.74	85.34	59.81				

*R - round *D - deeply fissured *V - V shaped O - other

TABLE 28

SECTIONS OF WETASKIWIN MAXILLARY MOLARS FROM

MESIOLINGUAL CUSP TIP TO MESIOBUCCAL CUSP TIP

(N = 40)

	Depth of Fissure	Angle at base of Fissure	Distance between cusp tips	Shape of base of fissure			
				R*	D*	V*	O
	15.94	99	61.78		x		
	23.14	84	54.43	x			
	24.31	101	68.90			x	
	24.13	101	60.47			x	
	32.50	75	57.24			x	
	24.91	81	58.82			x	
	22.66	98	63.36			x	
	16.07	117	53.61	x			
	14.67	113	64.40		x		
	24.90	100	61.76	x			
	27.79	77	62.40		x		
	26.77	87	67.76			x	
	21.17	98	61.37			x	
	21.83	91	58.03	x			
	25.83	79	68.44			x	
	28.53	93	70.20	x			
	27.44	69	51.40			x	
	24.30	91	60.86			x	
	26.10	84	58.15		x		
	21.60	94	61.19			x	
	26.21	73	57.14			x	
	22.90	96	53.86	x			
	22.41	99	62.97			x	
	27.10	81	56.85			x	
	26.70	81	53.80	x			
	23.13	90	54.50			x	
	29.58	87	63.16			x	
	28.16	79	59.11		x		
	23.64	87	51.27			x	
	24.13	95	56.56			x	
	25.78	76	55.24			x	
	25.07	89	59.27	x			
	22.50	81	58.47			x	
	21.54	91	64.55		x		
	22.85	75	53.90			x	
	27.24	79	49.35			x	
	27.26	90	65.94			x	
	20.19	95	59.17			x	
	22.28	80	74.18			x	
	15.76	99	63.06		x		
TOTAL	959.02	3549	2394.90	8	7	25	0
MEAN	23.98	88.73	59.87				

*R - round *D - deeply fissured *V - V shaped O - other

TABLE 29

SECTIONS OF CAMROSE MANDIBULAR MOLARS FROM

DISTOLINGUAL CUSP TIP TO BUCCAL (MIDDLE) CUSP TIP

(N = 36)

	Depth of Fissure	Angle at base of Fissure	Distance between cusp tips	Shape of base of fissure			
				R*	D*	V*	O
	18.33	111	48.34	x			
	20.00	96	52.40			x	
	19.37	84	44.05		x		
	18.74	90	54.42			x	
	23.06	60	58.54	x			
	21.71	95	55.60		x		
	22.39	103	63.26			x	
	26.28	79	63.95	x			
	25.37	84	60.48			x	
	20.80	80	49.46		x		
	20.87	88	51.50		x		
	23.00	85	60.61	x			
	20.69	98	54.95	x			
	23.75	98	59.21			x	
	23.28	88	60.28			x	
	23.41	71	55.77	x			
	14.90	109	44.17	x			
	25.65	77	57.84			x	
	23.57	87	65.52	x			
	20.74	86	58.06		x		
	22.74	95	58.50	x			
	20.95	84	51.90			x	
	30.69	68	57.19		x		
	16.67	99	53.60	x			
	24.40	80	54.02			x	
	21.90	101	64.20				x
	20.05	71	53.25		x		
	24.17	85	59.20	x			
	18.21	96	50.26			x	
	20.20	93	56.74	x			
	20.16	82	65.14	x			
	27.89	80	65.35			x	
	18.00	86	50.50			x	
	23.07	60	48.15		x		
	14.28	100	51.90	x			
	20.86	68	42.25		x		
TOTAL	802.10	3033	1949.82	14	9	12	1
MEAN	22.28	84.25	54.16				

*R - round *D - deeply fissured *V - V shaped O - other

TABLE 30

SECTIONS OF WETASKIWIN MANDIBULAR MOLARS FROM

DISTOLINGUAL CUSP TIP TO BUCCAL (MIDDLE) CUSP TIP

(N = 29)

	Depth of Fissure	Angle at base of Fissure	Distance between cusp tips	Shape of base of fissure			
				R*	D*	V*	O
	22.94	97	61.57	x			
	21.85	91	57.50			x	
	20.92	75	50.71		x		
	20.87	73	48.60	x			
	24.00	71	50.95			x	
	20.20	84	53.85		x		
	22.76	60	57.46		x		
	22.27	87	53.90	x			
	18.00	97	52.40	x			
	20.41	85	54.43			x	
	22.10	89	56.62			x	
	22.10	77	60.00			x	
	20.85	77	53.00			x	
	22.74	84	70.15			x	
	22.67	99	55.00			x	
	20.55	97	57.04			x	
	25.22	100	65.25			x	
	23.00	108	65.44			x	
	20.94	87	61.10	x			
	14.76	128	57.94	x			
	21.12	108	65.20			x	
	17.30	92	51.10	x			
	14.20	100	55.35				x
	22.24	95	51.81	x			
	23.66	90	58.00			x	
	20.16	88	58.94			x	
	21.00	84	51.17			x	
	16.64	116	51.33	x			
	23.88	74	63.93	x			
TOTAL	609.35	2613	1649.80	10	3	15	1
MEAN	21.01	90.1	56.89				

*R - round *D - deeply fissured *V - V shaped O - other

TABLE 31

SECTIONS OF CARIOUS MANDIBULAR MOLARS FROM

MESIOLINGUAL CUSP TIP TO BUCCAL (MIDDLE) CUSP TIP

(N = 38)

	Depth of Fissure	Angle at base of Fissure	Distance between cusp tips	Shape of base of fissure			
				R*	D*	V*	O
	28.34	110	66.93				x
	24.13	108	66.61				x
	26.71	97	73.90			x	
	23.38	97	71.86		x		
	28.17	96	61.05			x	
	28.27	72	66.50	x			
	36.36	53	66.61				x
	22.77	78	68.15	x			
	26.60	78	68.30			x	
	26.15	100	75.76	x			
	27.44	103	64.15	x			
	27.95	102	69.76			x	
	26.83	69	58.95		x		
	23.86	68	60.84				x
	20.20	69	59.47		x		
	20.16	88	56.35			x	
	25.40	87	71.54	x			
	26.93	69	51.33		x		
	31.46	91	62.68		x		
	26.85	101	67.52	x			
	28.57	98	68.17	x			
	31.50	70	65.80			x	
	25.82	105	71.15	x			
	22.00	106	65.95	x			
	27.87	93	73.55			x	
	27.07	94	73.90			x	
	24.23	72	69.75	x			
	26.13	80	74.06	x			
	26.69	83	71.00		x		
	22.40	93	75.16				x
	22.40	85	60.30	x			
	24.75	84	64.52			x	
	24.20	106	71.00	x			
	26.70	92	74.32	x			
	24.65	85	67.63	x			
	26.20	80	68.33	x			
	28.15	88	82.30			x	
	23.75	93	68.21			x	
TOTAL	991.75	3337	2573.27	16	6	11	5
MEAN	26.08	87.82	67.72				

*R - round *D - deeply fissured *V - V shaped O - other

TABLE 32

SECTIONS OF WETASKIWIN MANDIBULAR MOLARS FROM MESIOLINGUAL CUSP TIP TO BUCCAL (MIDDLE) CUSP TIP

(N = 30)

Depth of Fissure	Angle at base of Fissure	Distance between cusp tips	Shape of base of fissure			
			R*	D*	V*	O
20.41	104	64.85			x	
21.60	90	72.00	x			
23.07	85	64.30		x		
27.36	85	61.33			x	
24.36	93	60.00			x	
31.20	81	69.84			x	
22.10	99	60.37	x			
16.86	90	60.93		x		
24.10	96	62.40	x			
22.14	97	62.46	x			
21.92	107	66.52	x			
21.50	75	68.61	x			
24.67	92	66.90	x			
25.90	73	68.30	x			
20.65	118	68.64	x			
21.45	99	71.53	x			
22.78	103	68.35				x
27.75	102	68.90		x		
21.40	79	63.40			x	
18.40	99	64.67				x
21.92	112	75.75	x			
23.05	102	75.11				x
21.74	100	76.45		x		
20.45	93	72.76	x			
23.18	93	71.10	x			
23.40	92	71.08				x
15.17	115	71.03		x		
27.80	78	66.60			x	
26.47	101	81.90			x	
25.55	78	69.16	x			
TOTAL 688.35	2831	2045.24	14	5	7	4
MEAN 22.94	94.36	68.17				

*R - round *D - deeply fissured *V - V shaped O - other

TABLE 33

SECTIONS OF CAMROSE MANDIBULAR MOLARS FROM
MESIOLINGUAL CUSP TIP TO MESIOBUCCAL CUSP TIP
(N = 38)

Depth of Fissure	Angle at base of Fissure	Distance between cusp tips	Shape of base of fissure			
			R*	D*	V*	O
18.17	102	48.86	x			
23.75	79	57.00		x		
19.40	87	49.60	x			
18.18	78	53.55	x			
15.00	112	61.72	x			
20.86	74	50.05	x			
15.34	108	54.30			x	
19.56	83	50.00		x		
18.25	101	52.54	x			
14.00	91	41.00	x			
19.20	81	52.05		x		
10.43	99	44.25	x			
18.56	98	50.57		x		
15.20	80	46.80	x			
17.44	110	51.66		x		
20.45	84	57.53	x			
19.75	87	43.32			x	
15.70	104	40.24	x			
14.63	76	50.91		x		
18.73	80	48.18		x		
17.22	84	45.00		x		
20.00	91	48.48	x			
19.83	100	47.60			x	
21.30	68	52.56	x			
17.84	75	44.00			x	
20.22	91	54.90	x			
18.66	88	46.31		x		
17.65	88	47.80			x	
18.05	93	52.53	x			
20.76	58	54.65		x		
18.56	107	56.96	x			
20.65	86	53.28			x	
18.50	96	52.66	x			
18.24	89	47.77			x	
20.57	77	53.54	x			
20.40	78	51.53	x			
16.15	90	42.82			x	
18.50	88	50.10	x			
TOTAL 695.66	3366	1914.62	20	10	8	0
MEAN 18.31	88.58	50.38				

*R - round *D - deeply fissured *V - V shaped O - other

TABLE 34

SECTIONS OF [illegible] MANDIBULAR MOLARS FROM
MESIOLINGUAL CUSP TIP TO MESIOBUCCAL CUSP TIP
(N = 42)

	Depth of Fissure	Angle at base of Fissure	Distance between cusp tips	Shape of base of Fissure			
				R*	D*	V*	O
	18.03	87	52.53			x	
	20.46	78	46.53		x		
	18.90	81	49.11			x	
	17.00	91	52.28	x			
	18.36	71	48.60			x	
	15.29	107	47.83	x			
	20.27	99	55.60			x	
	18.73	68	49.41		x		
	22.40	63	52.69		x		
	14.76	86	43.93			x	
	18.88	96	54.15			x	
	16.25	94	53.55	x			
	13.60	118	60.36			x	
	14.14	90	42.71	x			
	18.47	97	56.44			x	
	18.60	92	53.88		x		
	11.35	125	46.87				x
	19.14	96	48.71	x			
	16.45	101	49.64			x	
	16.84	90	53.78			x	
	18.23	120	60.21			x	
	18.00	87	57.04		x		
	14.24	116	46.91	x			
	14.41	101	44.64		x		
	18.44	97	50.66	x			
	18.28	90	52.36			x	
	19.28	102	44.26			x	
	17.79	94	49.85			x	
	20.11	70	42.14		x		
	18.37	69	45.60		x		
	18.26	98	45.58	x			
	17.80	83	50.64			x	
	18.46	89	51.21	x			
	19.90	75	54.75			x	
	17.45	86	59.98		x		
	16.07	118	53.96	x			
	18.83	78	52.67			x	
	12.03	122	55.57				x
	15.10	105	63.94			x	
	15.13	106	49.03	x			
	18.92	80	48.55	x			
	16.40	101	48.60	x			
TOTAL	727.38	3923	2134.07	13	9	18	2
MEAN	17.32	93.40	50.83				

*R - round *D - deeply fissured *V - V shaped O - other

TABLE 35

INCIDENCE AND SIZE OF CARABELLI'S CUSP

IN MAXILLARY MOLARS IN CAMROSE (LOW FLUORIDE)

AND WETASKIWIN (OPTIMUM FLUORIDE)

Camrose		Wetaskiwin	
Present	Size mm.	Present	Size mm.
x	8.86	x	7.10
x	7.61	x	6.67
x	16.16	x	17.74
x	8.68	x	5.76
x	12.65	x	10.86
x	6.35	x	7.46
x	10.63	x	11.93
x	15.45	x	6.49
no cusp		x	14.50
x	14.35	x	11.40
no cusp		no cusp	
no cusp		x	7.70
no cusp		x	11.50
no cusp		no cusp	
no cusp		x	11.50
x	7.94	x	11.65
x	6.55	no cusp	
x	7.80	x	20.20
x	10.41	x	21.56
no cusp		no cusp	
x	10.42	no cusp	
x	9.90	no cusp	
x	10.89	x	15.01
x	16.05	x	13.50
x	7.40	x	10.70
x	9.24	x	6.31
x	16.92	x	15.46
no cusp		x	11.94
x	20.00	x	10.50
no cusp		no cusp	
x	11.80	x	16.56
x	16.06	x	10.00
x	8.62	x	13.75
x	8.26	x	13.75
x	8.16	x	10.55
x	14.75	x	8.80
no cusp		x	14.15
x	10.20	no cusp	
x	22.63	no cusp	
no cusp		x	15.06
no cusp		no cusp	
no cusp			
no cusp			
TOTAL 29	334.74	31	376.06
MEAN	11.54		12.13

APPENDIX B

TRACINGS OF ENLARGED PHOTOGRAPHS
OF ALL SECTIONED MOLARS USED
IN THE STUDY

Fig. 15.--Tracings of enlarged photographs of Camrose maxillary first permanent molars sectioned from distolingual cusp tip to distobuccal cusp tip.

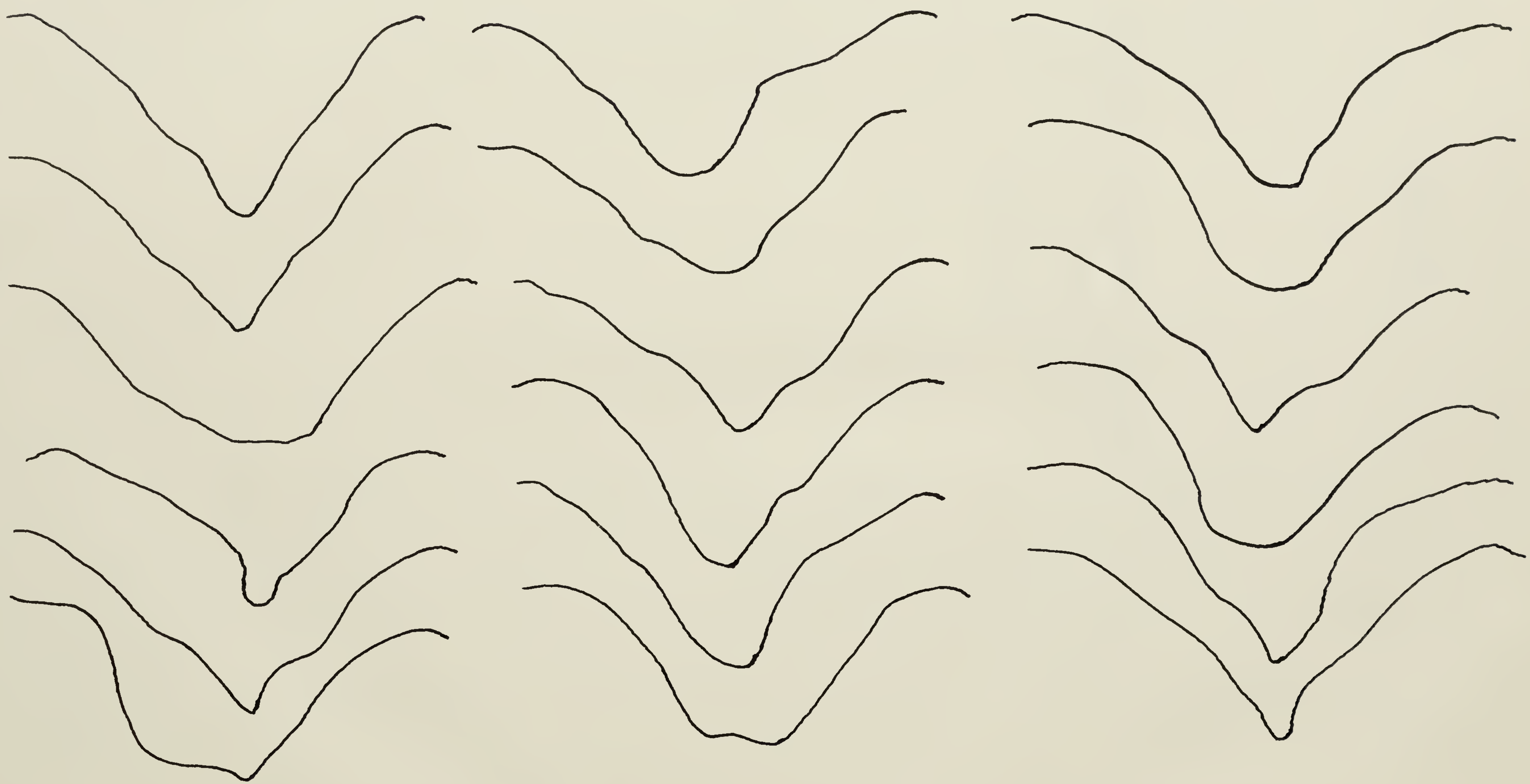


Fig. 16.--Tracings of enlarged photographs of Wetaskiwin maxillary first permanent molars sectioned from distolingual cusp tip to distobuccal cusp tip.

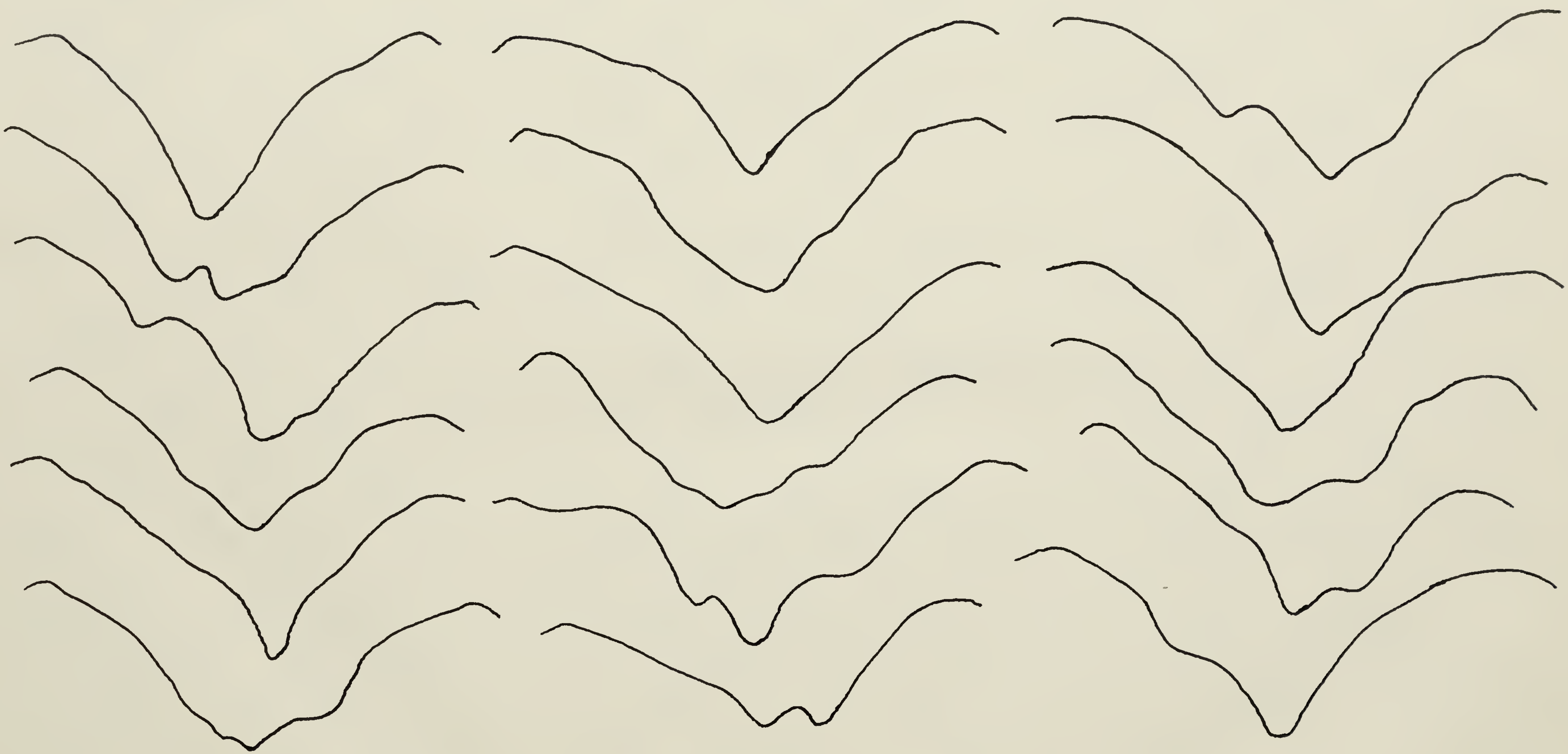
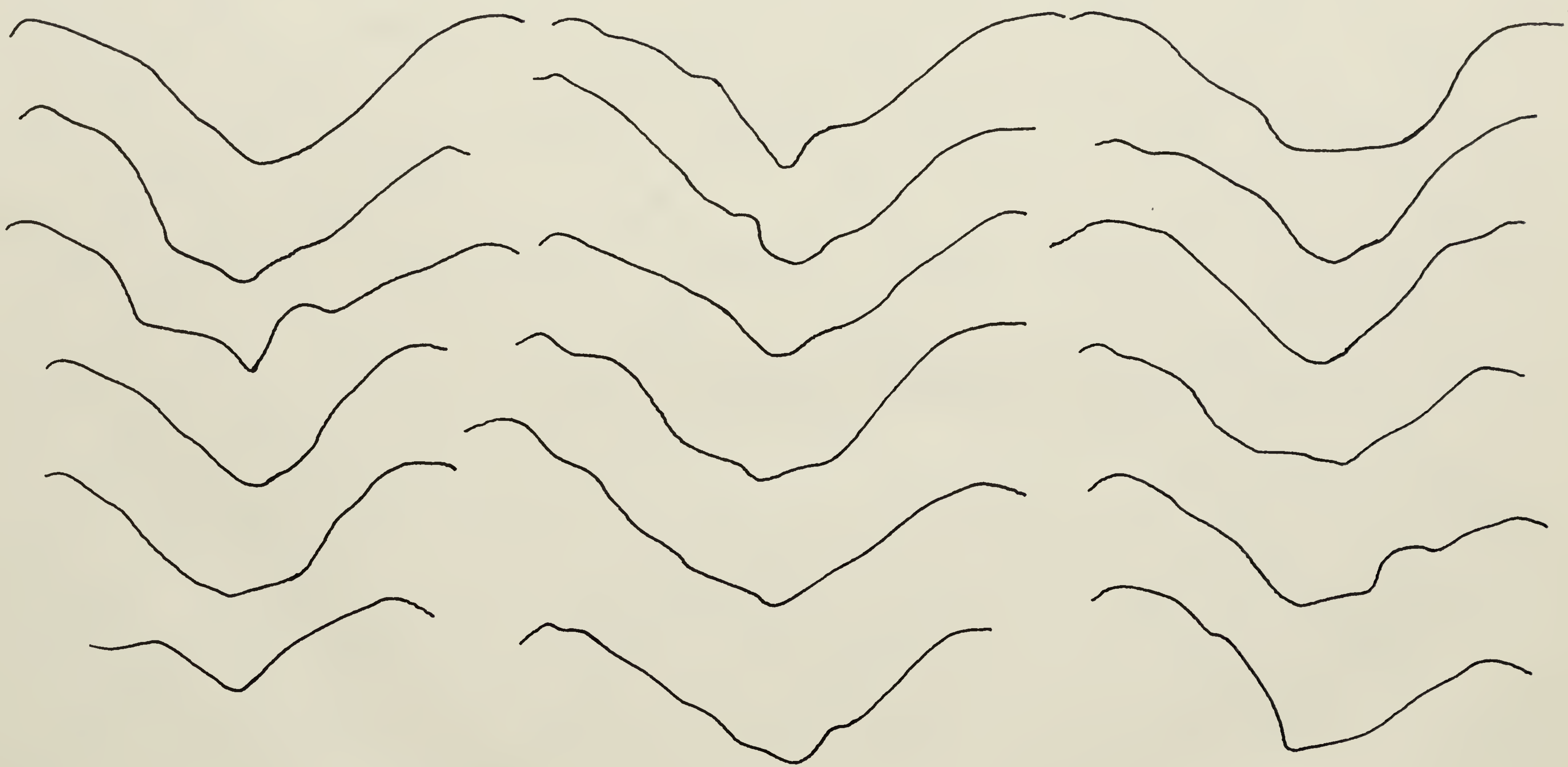


Fig. 17.--Tracings of enlarged photographs of Camrose maxillary first permanent molars sectioned from distobuccal cusp tip to mesiolingual cusp tip.



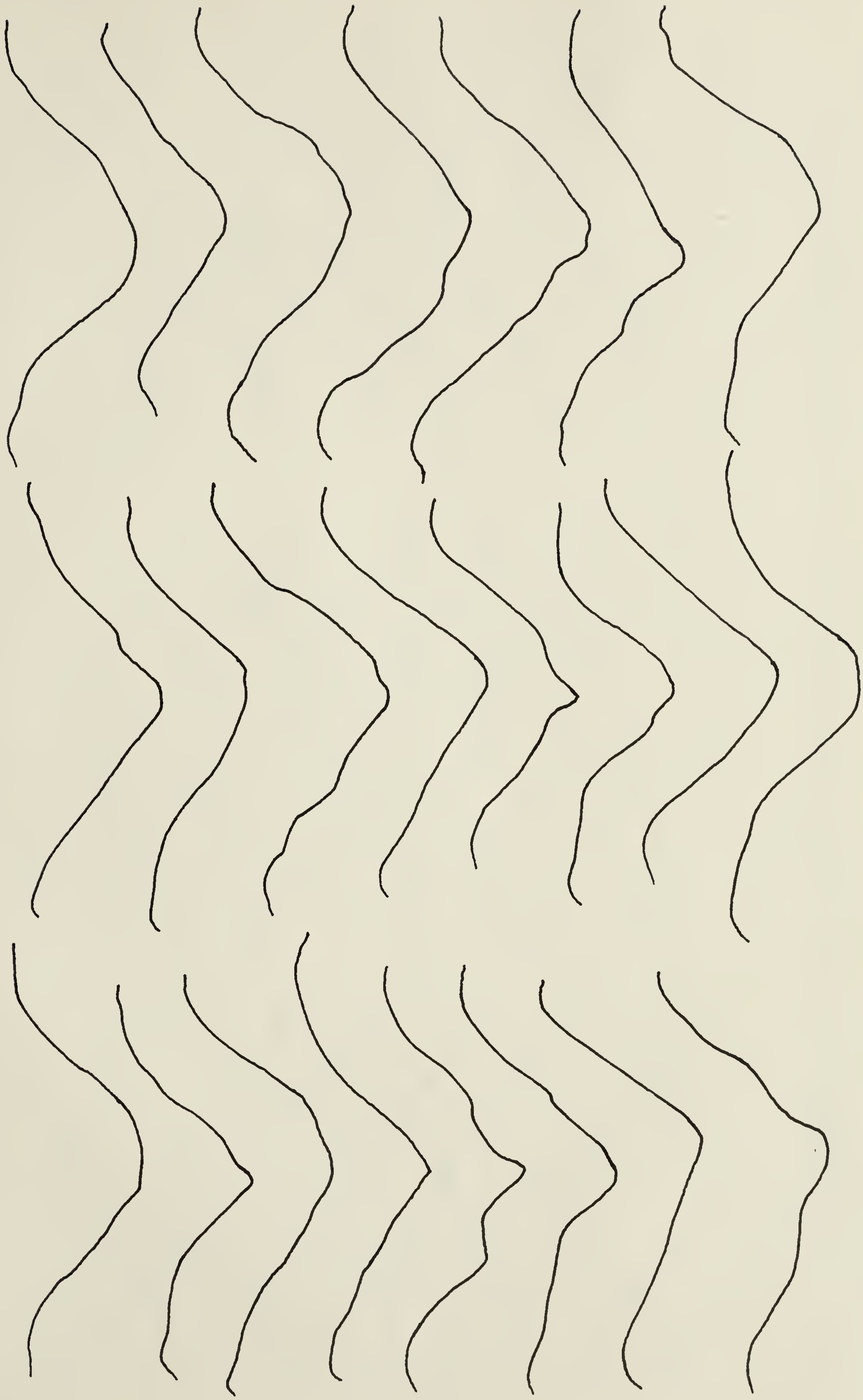


Fig. 18.--Tracings of enlarged photographs of Wetaskiwin maxillary first permanent molars sectioned from distobuccal cusp tip to mesiolingual cusp tip.

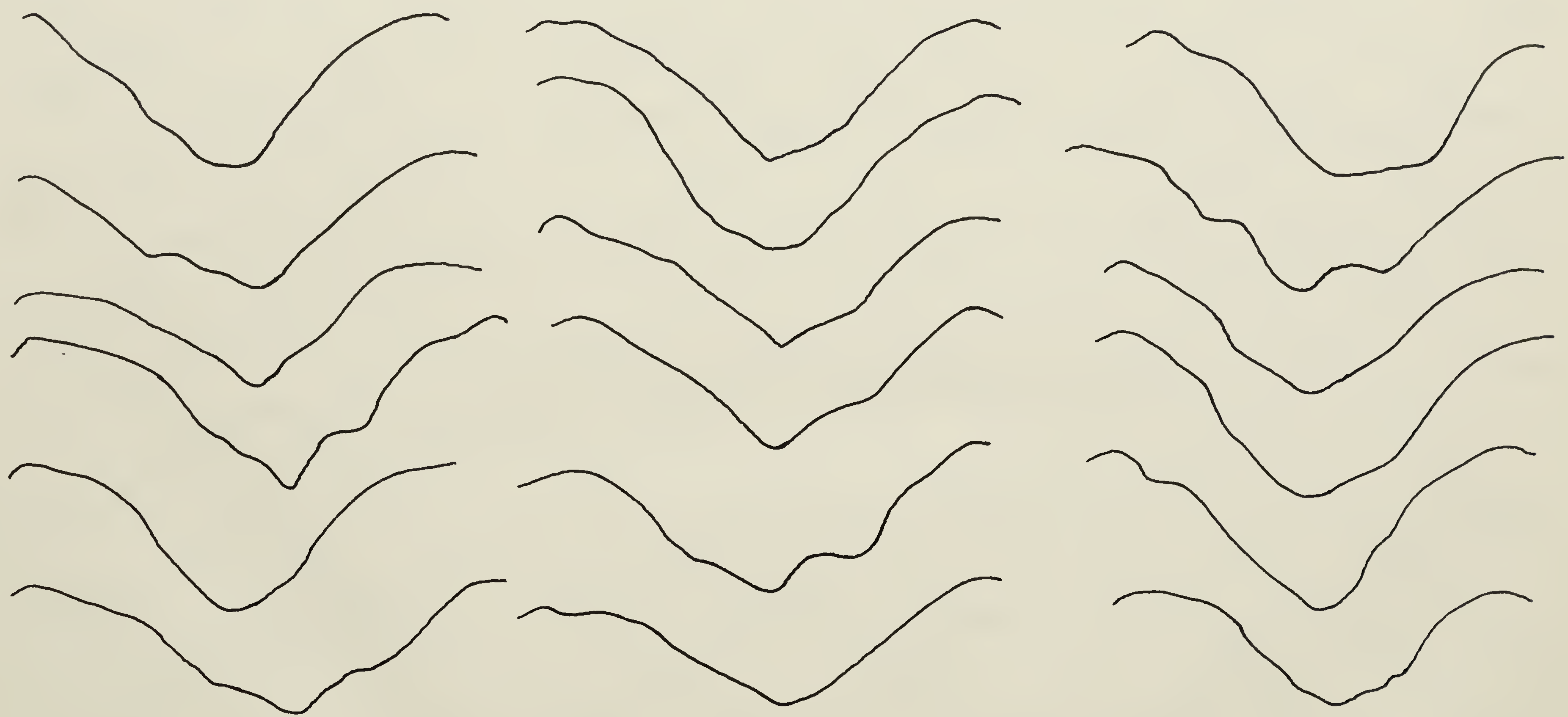
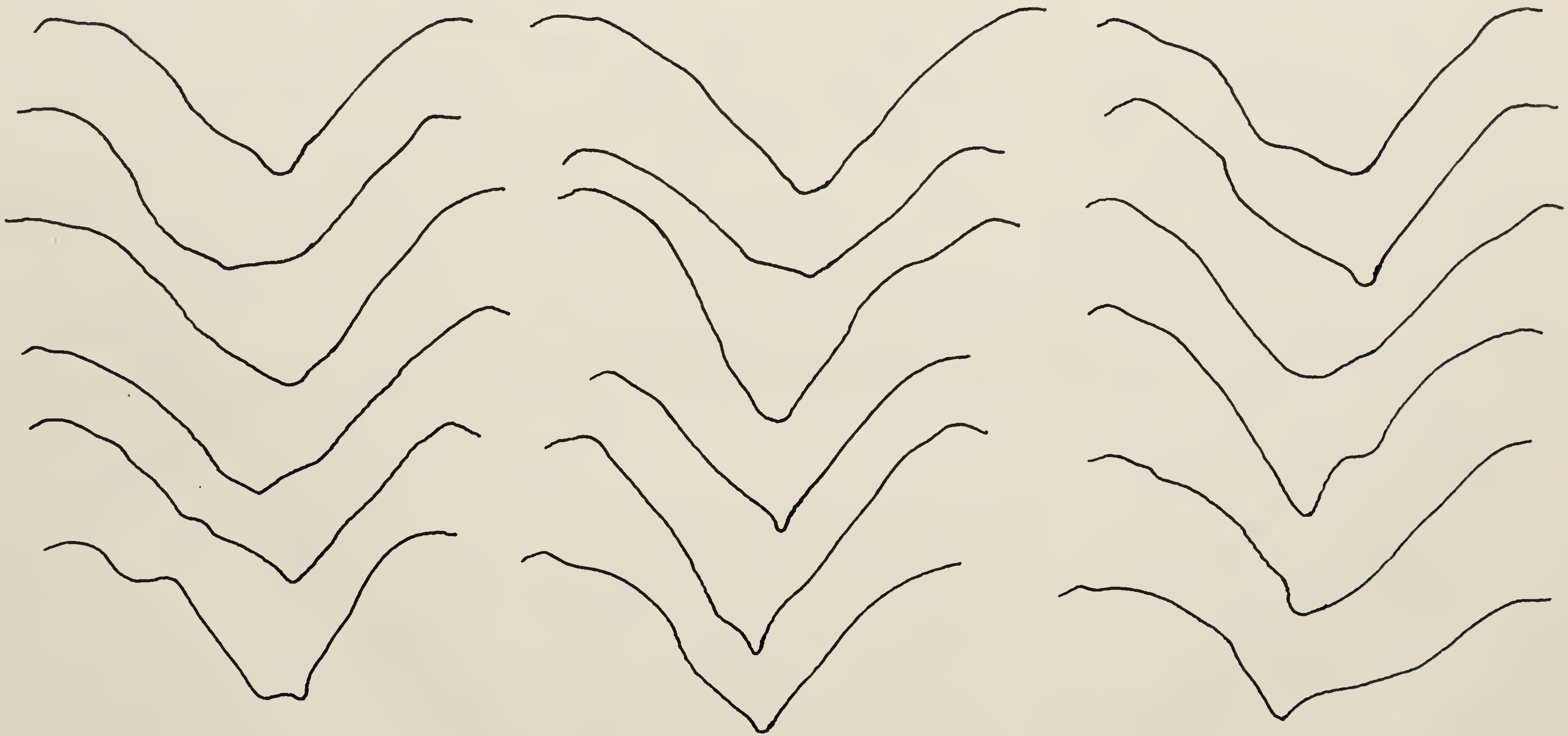


Fig. 19.--Tracings of enlarged photographs of Camrose maxillary first permanent molars sectioned from mesiolingual cusp tip to mesiobuccal cusp tip.



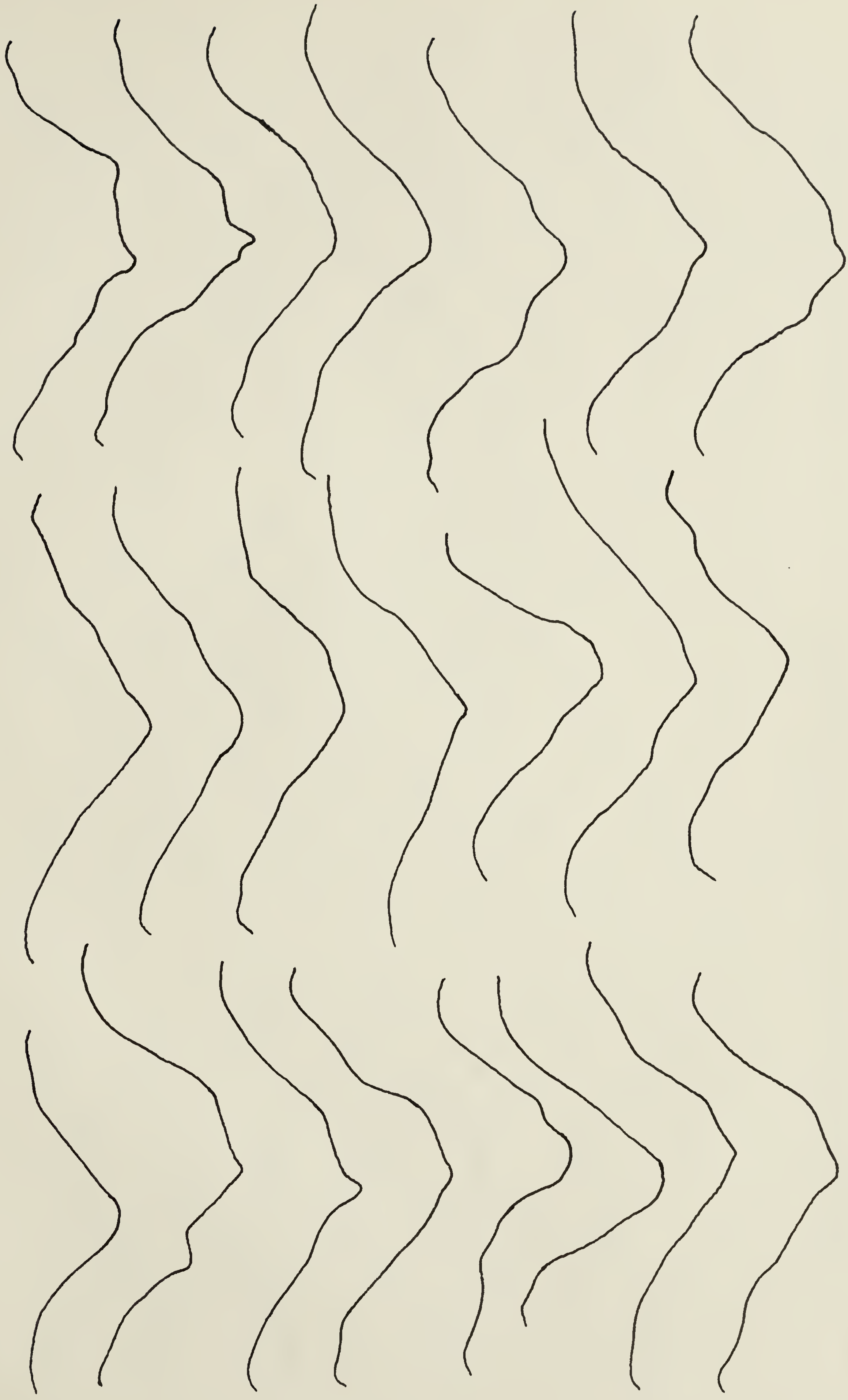
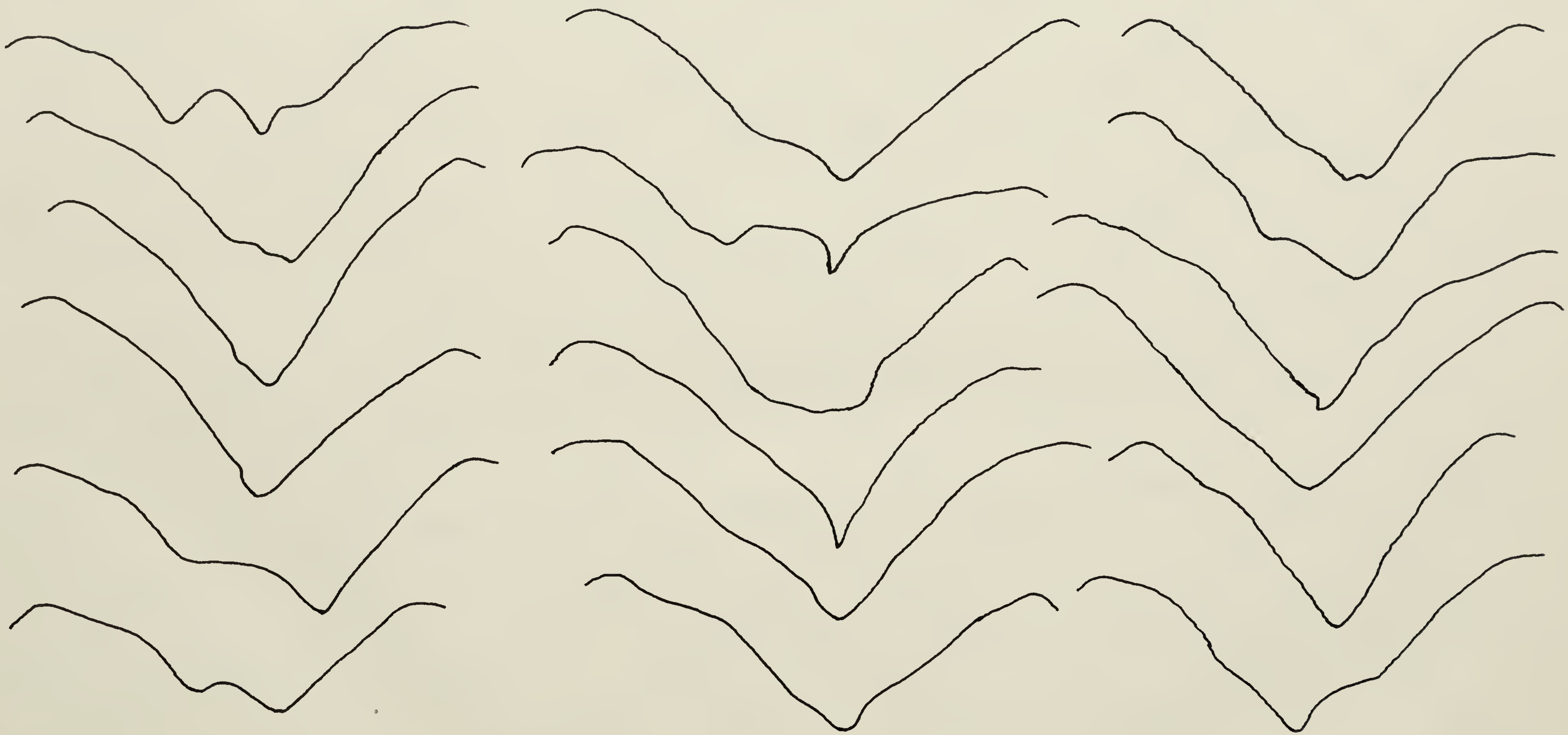


Fig. 20.--Tracings of enlarged photographs of Wetaskiwin maxillary first permanent molars sectioned from mesiolingual cusp tip to mesiobuccal cusp tip.



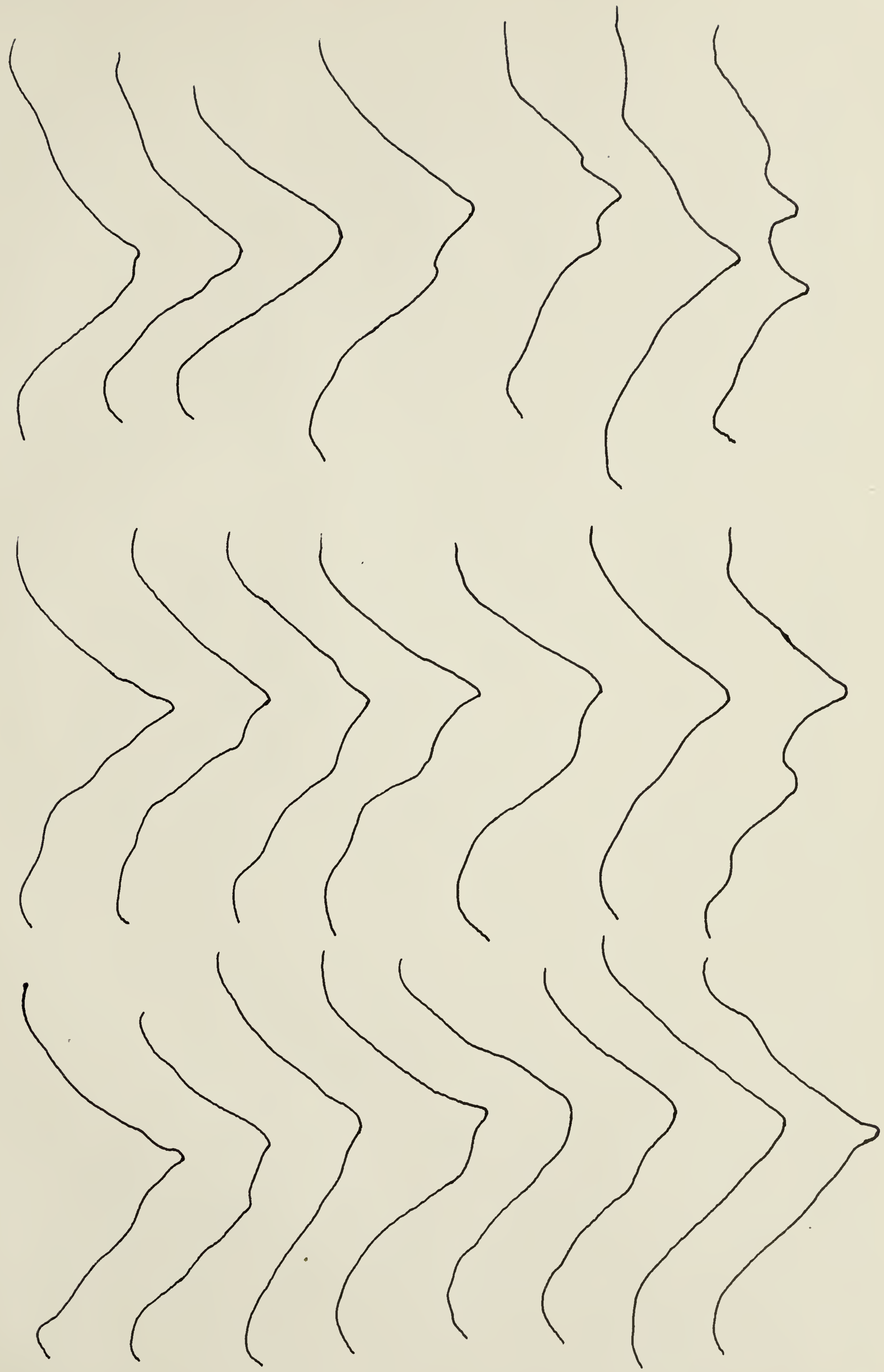


Fig. 21.--Tracings of enlarged photographs of Camrose mandibular first permanent molars sectioned from distolingual cusp tip to buccal (middle) cusp tip.

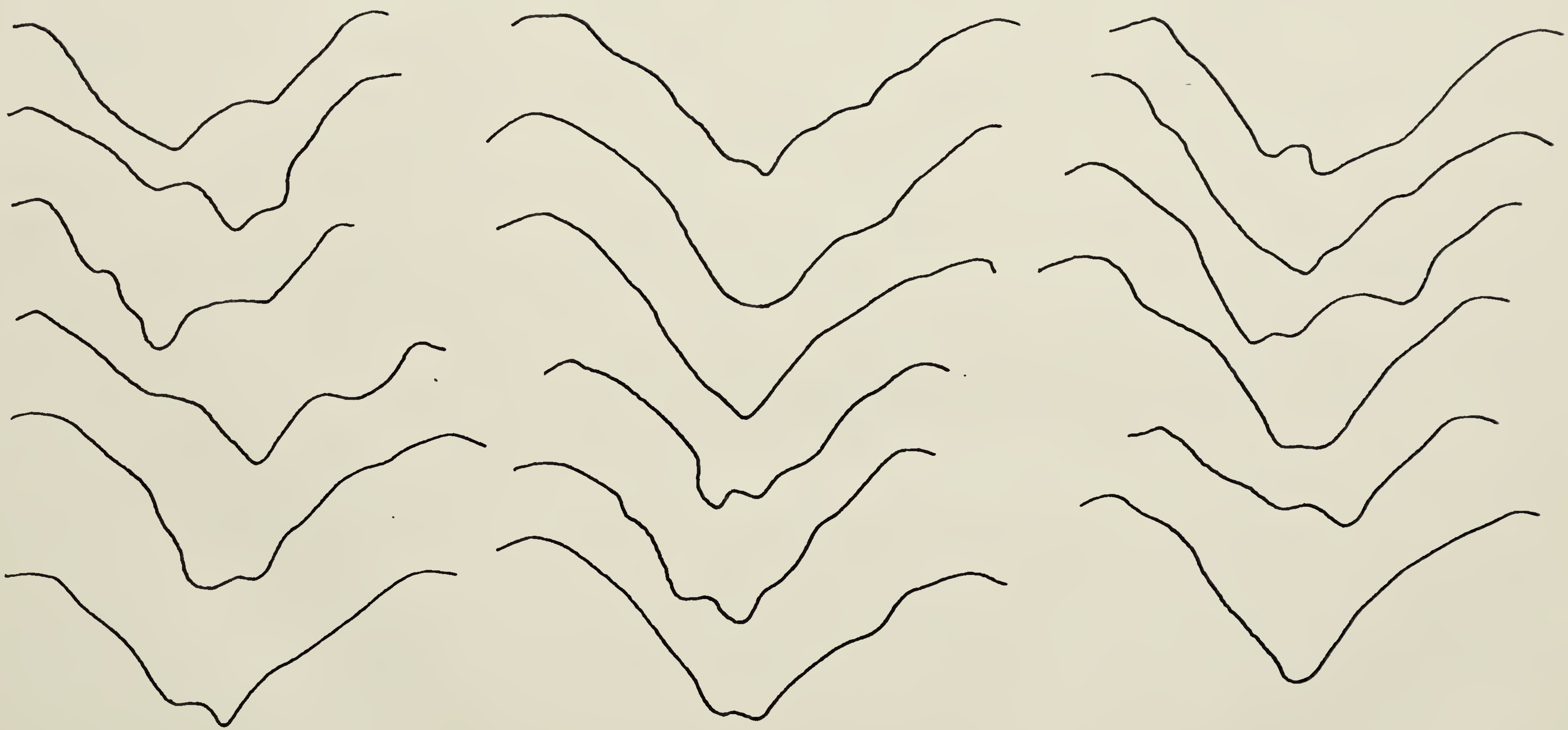
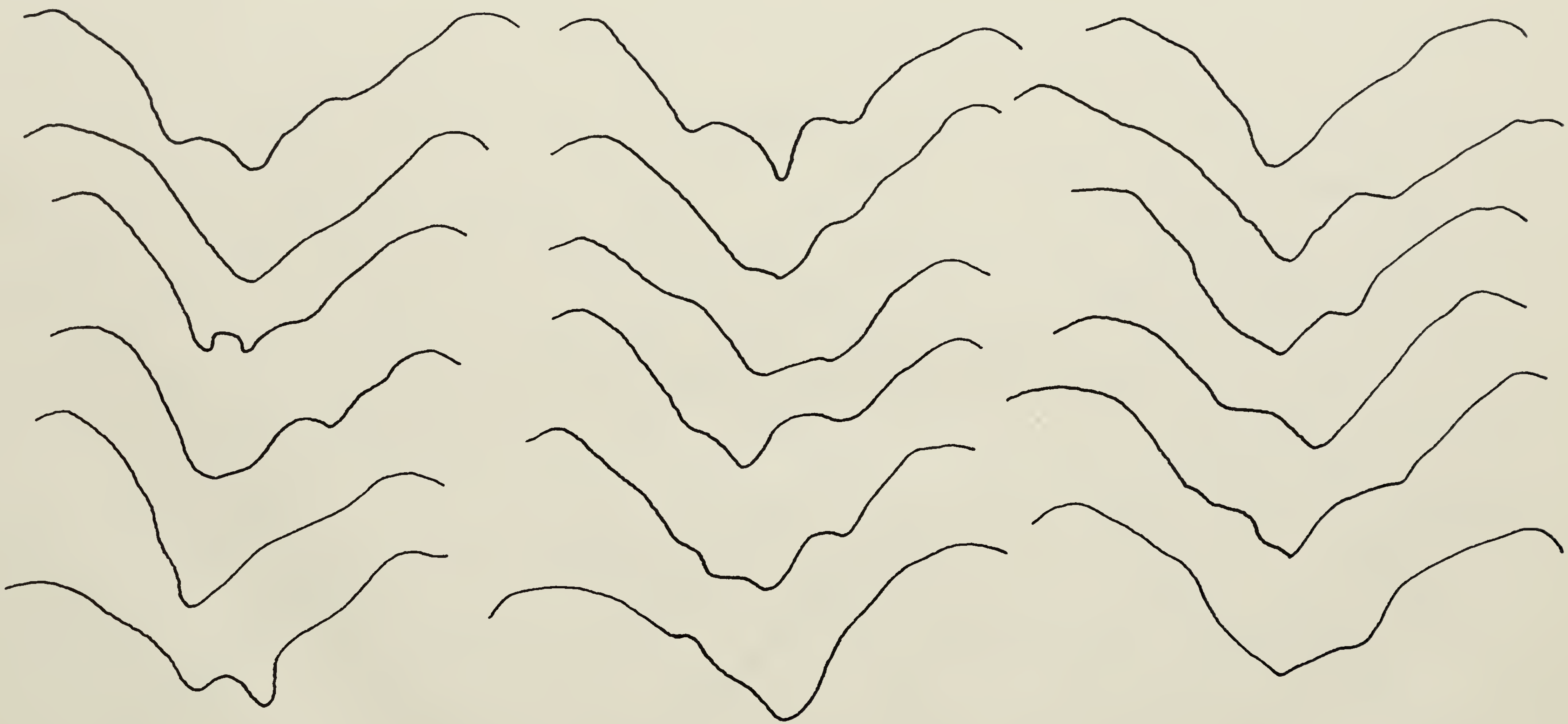


Fig. 22.--Tracings of enlarged photographs of Wetaskiwin mandibular first permanent molars sectioned from distolingual cusp tip to buccal (middle) cusp tip.



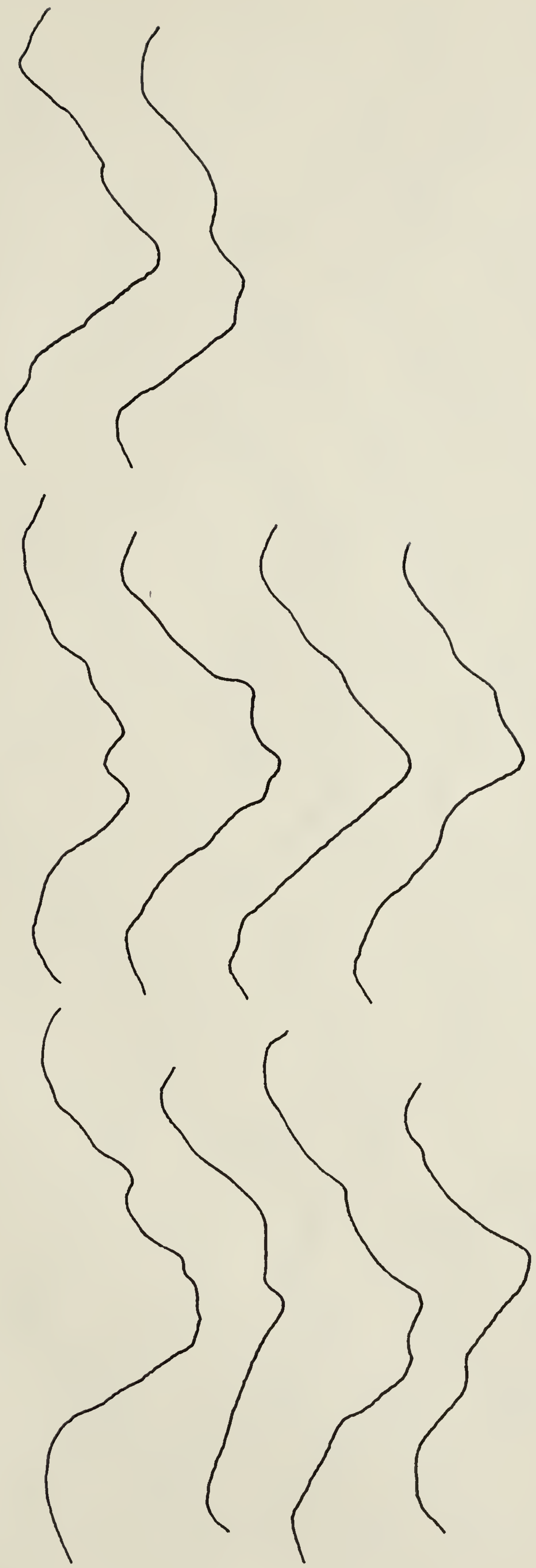
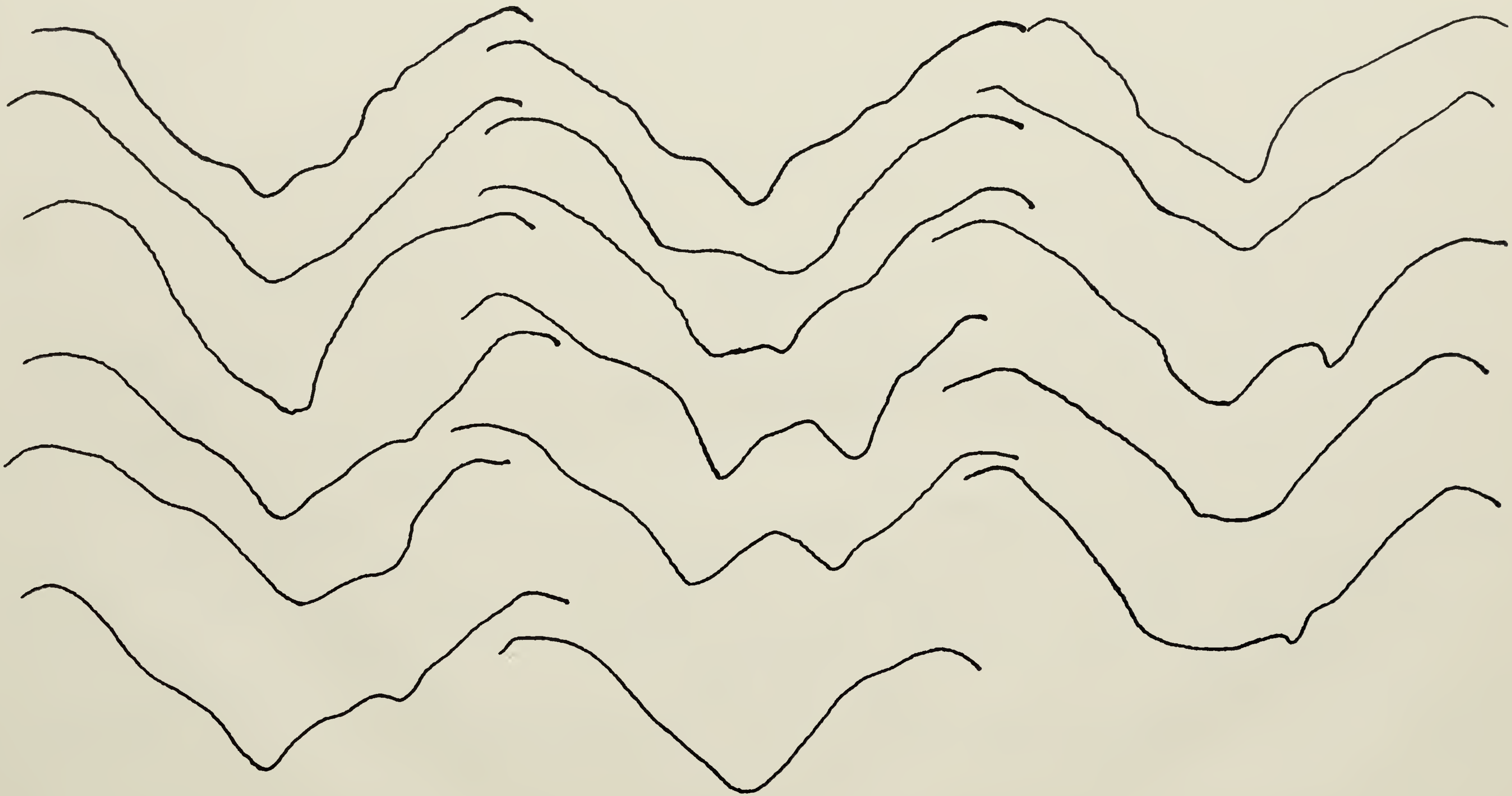


Fig. 23.--Tracings of enlarged photographs of Camrose mandibular first permanent molars sectioned from mesiolingual cusp tip to buccal (middle) cusp tip.



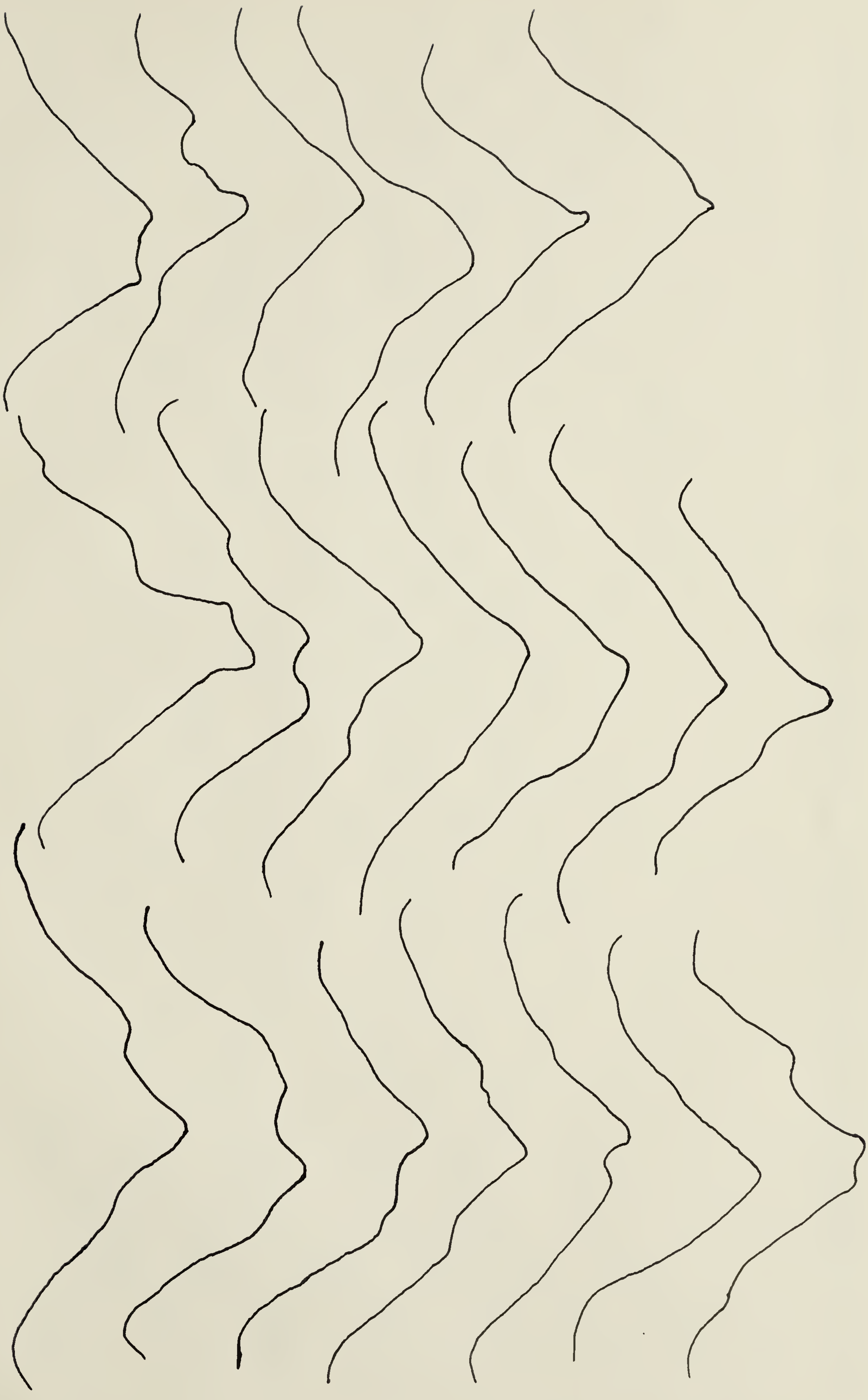


Fig. 24.--Tracings of enlarged photographs of Wetaskiwin mandibular first permanent molars sectioned from mesiolingual cusp tip to buccal (middle) cusp tip.

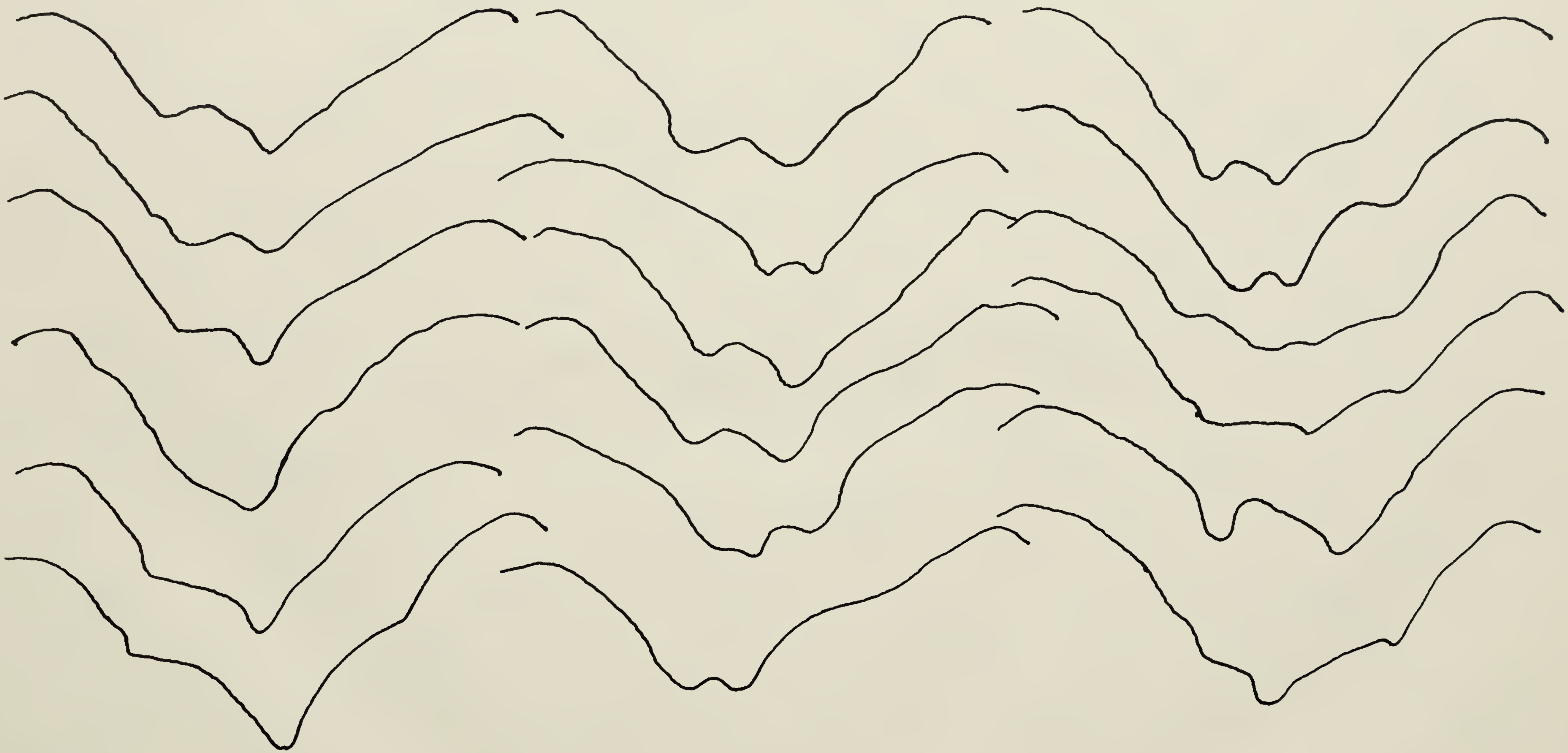


Fig. 25.--Tracings of enlarged photographs of Camrose mandibular first permanent molars sectioned from mesiolingual cusp tip to mesiobuccal cusp tip.

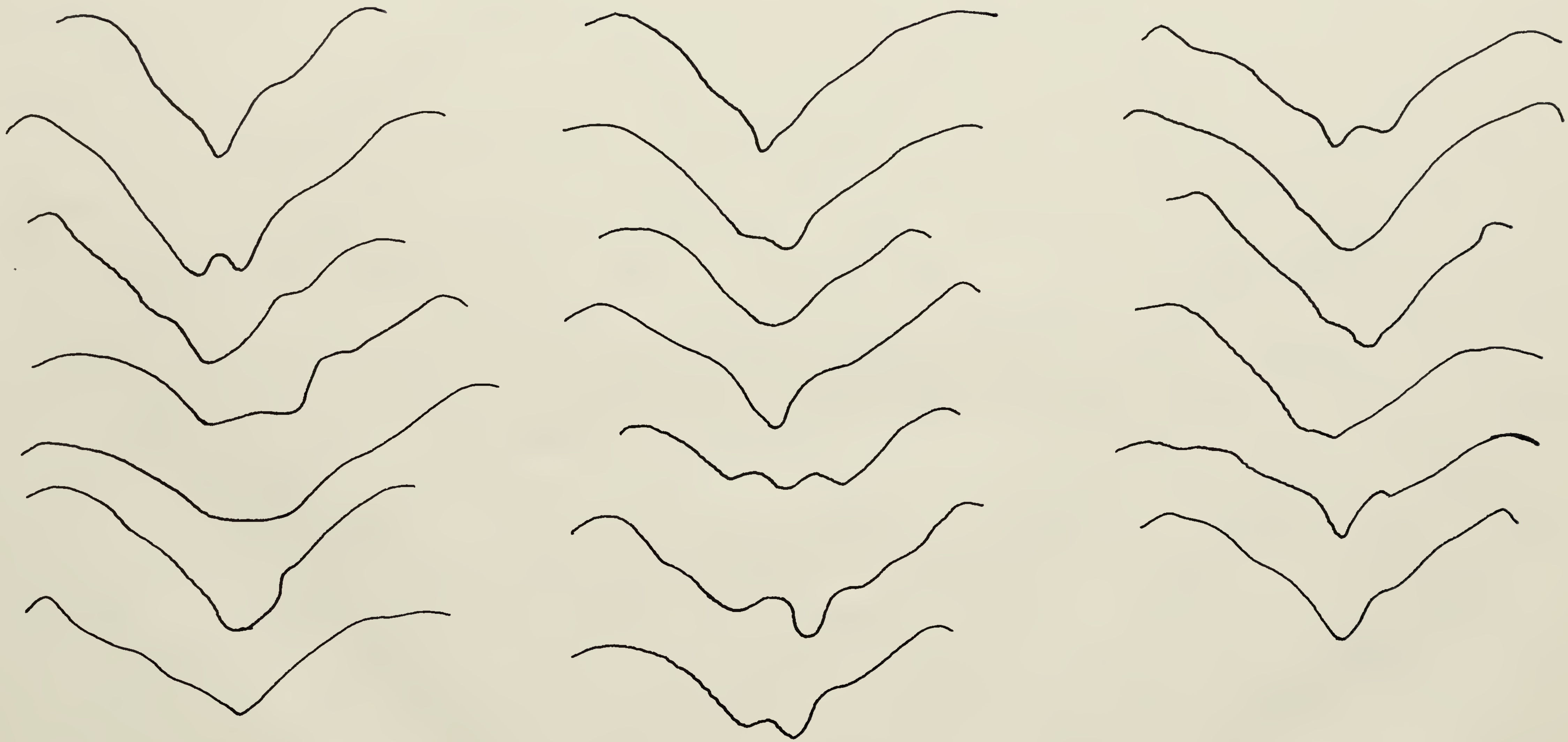
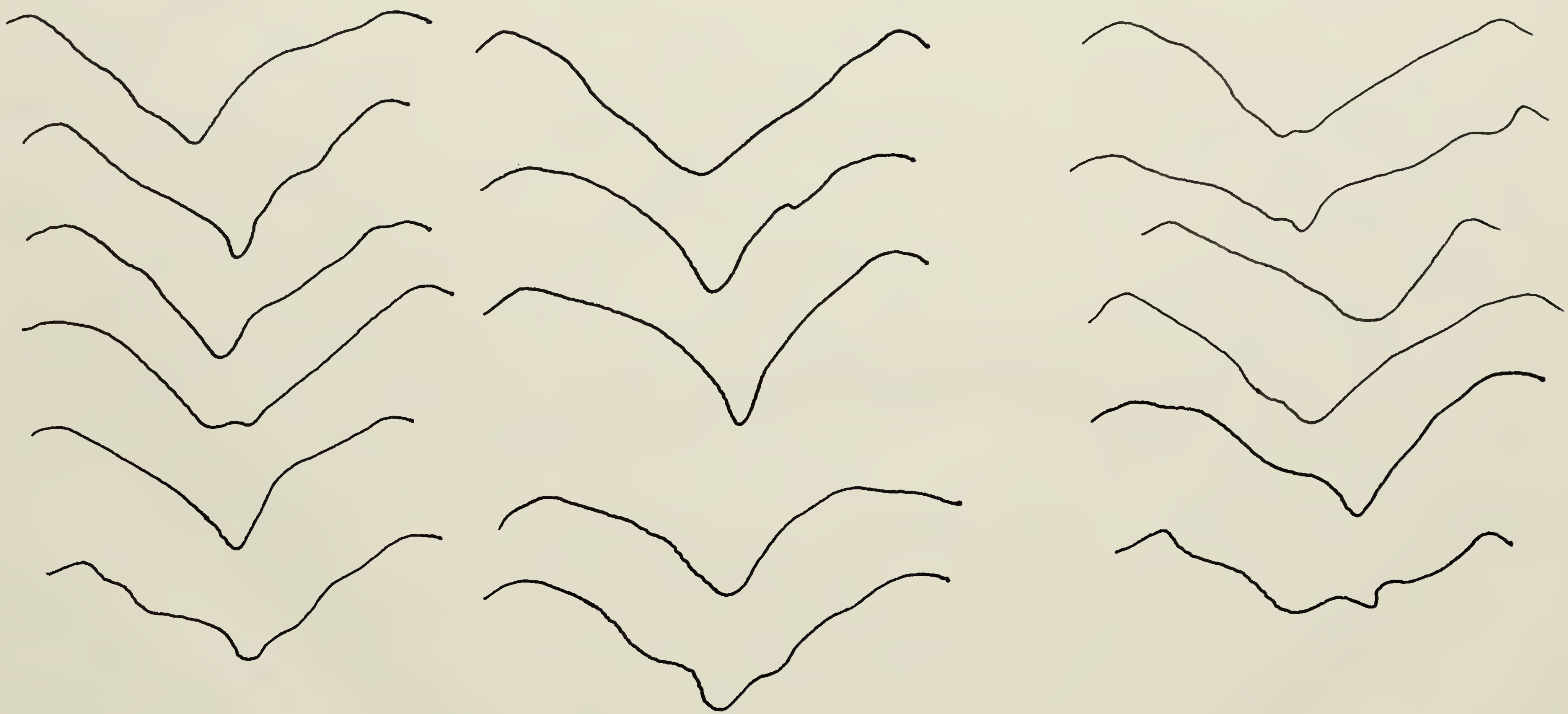
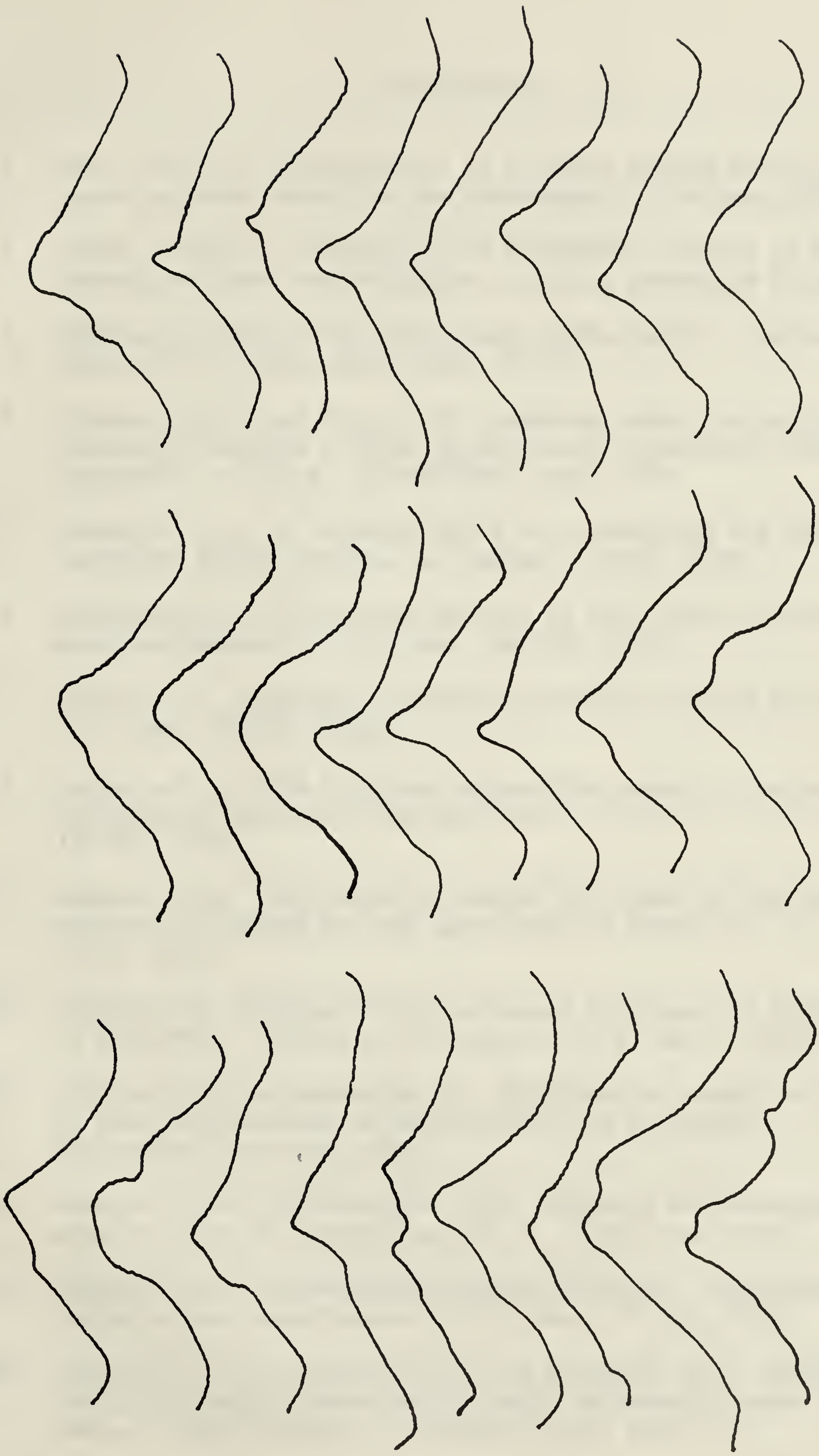


Fig. 26.--Tracings of enlarged photographs of Wetaskiwin mandibular first permanent molars sectioned from mesiolingual cusp tip to mesiobuccal cusp tip.





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